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European Refuse Fired Energy Systems: Evaluation of Design Practices. Volume XVIII: Paris Issy-Les Moulineaux, France

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The evaluation, which consists of two volumes of text and 15 trip reports, analyzes the experiences of the Europeans with waste to energy systems. The text is a compilation of the data obtained during visits to 15 major European refuse fired energy systems and visits to systems vendors, government agencies and other plants.

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EUROPEAN REFUSE FIRED ENERGY SYSTEMS

EVALUATION OF DESIGN PRACTICES

Paris Issy-Les Moulineaux
France

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Volume 18

U.S. ENVIRONMENTAL PROTECTION AGENCY

1979

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An environmental protection publication (SW-176c.18) in the solid waste management series.

PREFACE

This trip report is one of a series of 15 trip reports on European waste-to-energy systems prepared for the U.S. Environmental Protection Agency. The overall objective of this investigation is to describe and analyze European plants in such ways that the essential factors in their successful operation can be interpreted and applied in various U.S. communities. The plants visited are considered from the standpoint of environment, economics and technology.

The material in this report has been carefully reviewed by the European grate or boiler manufacturers and respective American licensees. Nevertheless, Battelle Columbus Laboratories maintains ultimate responsibility for the report content. The opinions set forth in this report are those of the Battelle staff members and are not to be considered by EPA policy.

The intent of the report is to provide decision making information. The reader is thus cautioned against believing that there is enough information to design a system. Some proprietary information has been deleted at the request of vendors. While the contents are detailed, they represent only the tip of the iceberg of knowledge necessary to develop a reliable, economical and environmentally beneficial system.

The selection of particular plants to visit was made by Battelle, the American licensees, the European grate manufacturers, and EPA. Purposely, the sampling is skewed to the "better" plants that are models of what the parties would like to develop in America. Some plants were selected because many features envolved at that plant. Others were chosen because of strong American interest in co-disposal of refuse and sewage sludge.

The four volumes plus the trip reports for the 15 European plants are available through The National Technical Information Service, Springfield, Virginia 22161. NTIS numbers for the volumes and ordering information are contained in the back of this publication. Of the 19 volumes only the Executive Summary and Inventory have been prepared for wide distribution.

ORGANIZATION

The four volumes and 15 trip reports are organized the the following fashion:

VOLUME I

A EXECUTIVE SUMMARY
B INVENTORY OF WASTE-TO-ENERGY PLANTS
C DESCRIPTION OF COMMUNITIES VISITED
D SEPARABLE WASTE STREAMS
E REFUSE COLLECTION AND TRANSFER STATIONS
F COMPOSITION OF REFUSE
G HEATING VALUE OF REFUSE
H REFUSE GENERATION AND BURNING RATES PER PERSON
I DEVELOPMENT OF VISITED SYSTEMS

VOLUME II

J TOTAL OPERATING SYSTEM RESULTS
K ENERGY UTILIZATION
L ECONOMICS AND FINANCE
M OWNERSHIP, ORGANIZATION, PERSONNEL AND TRAINING

VOLUME III

P REFUSE HANDLING
Q GRATES AND PRIMARY AIR
R ASH HANDLING AND RECOVERY
S FURNACE WALL
T SECONDARY (OVERFIRE) AIR

VOLUME IV

U BOILERS
V SUPPLEMENTARY CO-FIRING WITH OIL, WASTE OIL AND SOLVENTS
W CO-DISPOSAL OF REFUSE AND SEWAGE SLUDGE
X AIR POLLUTION CONTROL
Y START-UP AND SHUT-DOWN
Z APPENDIX

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SUMMARY

The Issy-les-Moulineaux (ISSY) plant is located in a western suburb of Paris along the Seine River. It is owned by the City of Paris. However, it is operated by the Service du Traitment Industrial des Residus Urbans (TIRU) a profit oriented division of the federally owned Electricitie de France (EDF).

Issy is one of three thermal reduction facilities in Paris. Issy itself is the third plant at its location; other plants having been built in 1903, 1928 and this plant in 1962.

Four furnaces originally designed to burn 15 tonnes per hr each now are overloaded at 20 tonnes per hr each. This results in 1976 average consumption of 1,431 tonnes (1,574 tons) per day being burnt on the Martin reverse reciprocating grates.

The plant was chosen for this survey because of the long history of successful innovation to extend furnace life. The report discusses extensively how various high alumina and silicon carbide blocks and plastic material have extended the life of the furnace combustion chamber. Downstream boiler corrosion has been reduced with metal tube shields, air deflection baffles, plastic high alumina, plastic silicon carbide refractory, wide pass tube redesign and manual tube cleaning.

Depending on seasonal demand and prices, steam produced will first pass through a backpressure turbogenerator and then either through a condensing turbine or to the district heating system. The electricity is sold to TIRU's parent EDF for general distribution. Steam is sold to TIRU's sister company Compagnie Parisimne de Chauffage Urbain (CPCU) which in turn sells the steam to its district heating customers. Issy, in 1975, produced 12.3 percent of the total CPCU requirements.

Flue gases pass through 2-field electrostatic precipitors. The plant measures full air emissions every month to verify compliance and to monitor general plant operating conditions.

Economically, Issy is one of the better plants in Europe. Total annual costs (including amortization) total about $13 per ton. Half of these costs are recovered through sale of electricity and steam. The resultant net cost is about $6.50 per ton.

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OVERALL SYSTEM SCHEMATIC

Figure 6-1 displays the overall system schematic for the Issy plant.

COMMUNITY DESCRIPTION

Geography

The Issy plant is located in the Southwest of Paris along the Seine River as can be seen in Figure 6-2. The area along the river is flat but sufficiently above the river water level so that no excavation ground water problems were experienced.

Actually the name "Issy-les-Moulineaux" comes from the Paris suburb of that same name. The map also shows the location of the three other major facilities: Ivry, St. Ouen and Romanville. Ivry is similar to Issy. St. Ouen is an older 360,000 tons per year rotary kiln. The Romanville facility is now only a transfer station having ceased burning operations in 1969. Much of the Romanville waste is transferred to Issy at night. Throughout the report, reference will be made to the interaction of all four facilities.

The greater Paris metropolitan area population is 7,750,000; while that of the City of Paris is 2,790,00. Issy, a suburb, has a population of only 52,000. The remainder of the population is in the 53 other Parisian suburbs.

Government and Industry

The employment pattern in government and industry is diverse and balanced as one would expect of France's capital city and largest city. Heavy industry does not contribute much waste to the Issy plant.

With one exception, the city of Paris has a parallel organizational position with the other 54 suburbs. The plant, therefore, is not run by the cities of Paris or Issy, but by a Federally chartered organization: Electricite' de France. Actually the operations are controlled by its somewhat independent unit: Service du Traitement Industriel des Residus Urbains (TIRU). Much of the

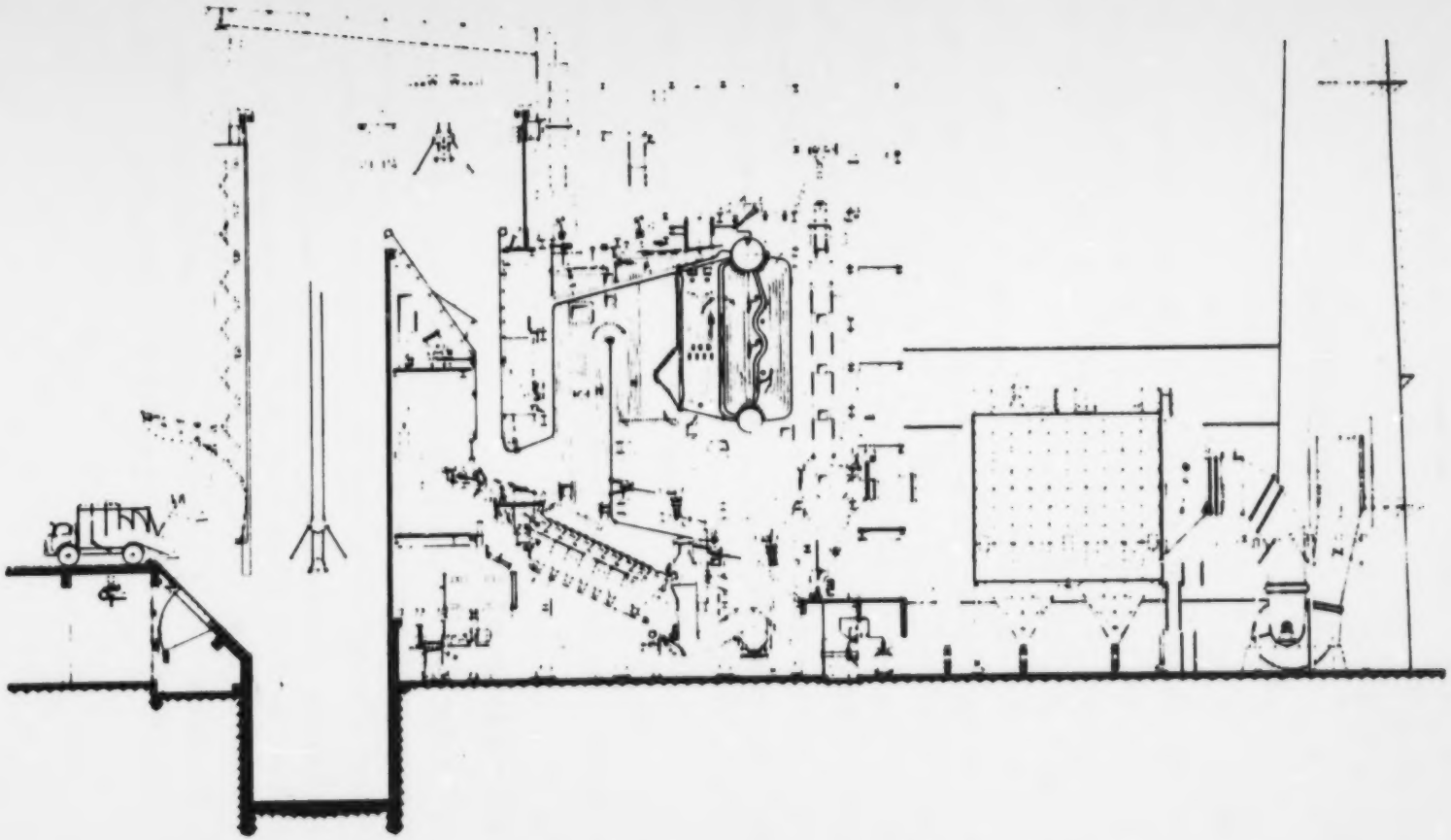

FIGURE 6-1. SKEMATIC CROSS SECTION OF THE PARIS-ISSY-LES MOULINEAUX PLANT

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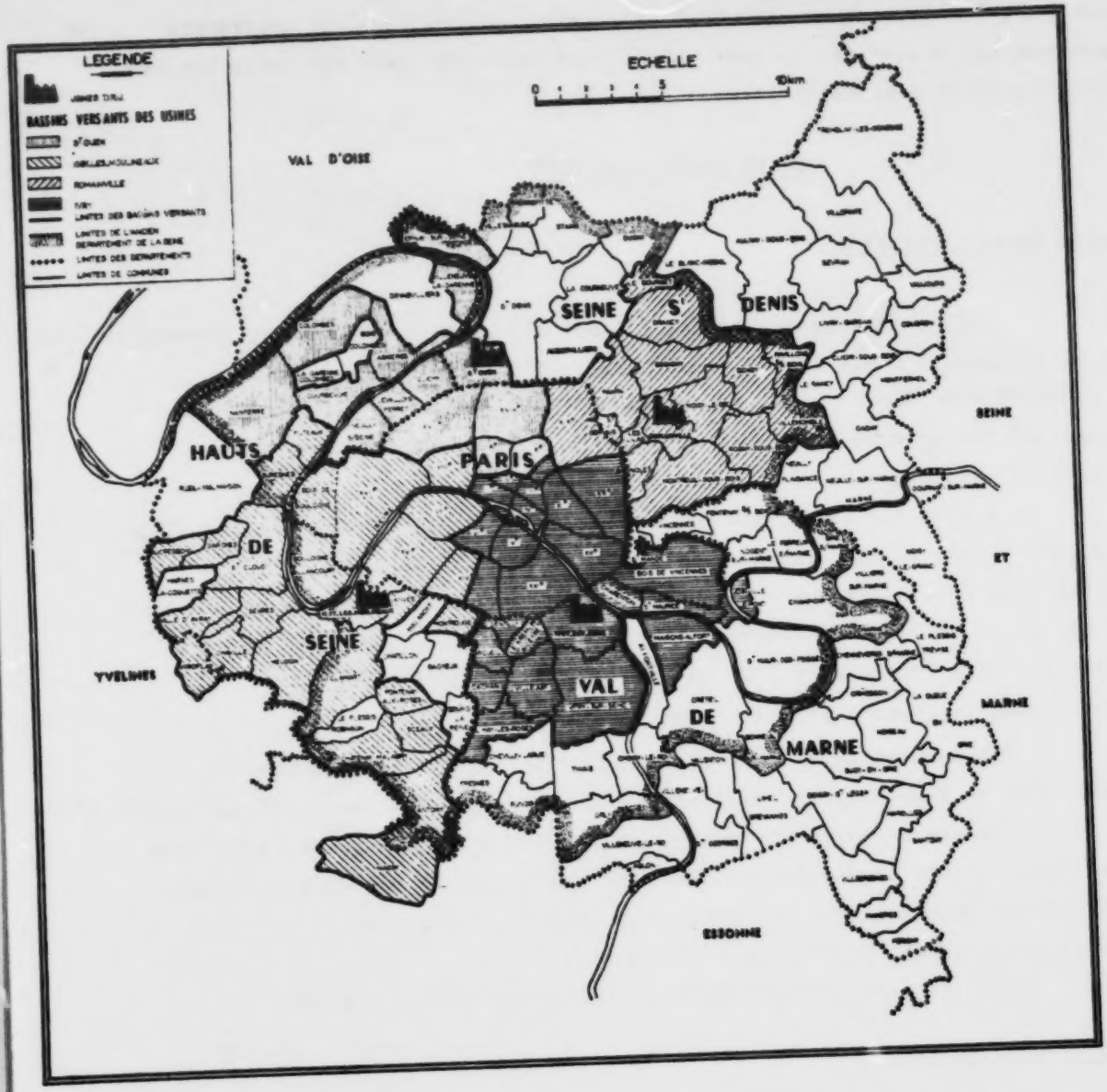

FIGURE 6-2 . WASTE GENERATION AREA AND TREATMENT PLANTS FOR THE PARIS, FRANCE PLANTS THAT TREAT URBAN WASTE

information in this report was supplied by the officials of this "Service for the Industrial Treatment of Urban Waste".

The one exception mentioned is that the Department of Seine financed and built the Issy plant. Several years ago, General DeGaulle rearranged governmental activities so that the City of Paris now owns the units but has no operational responsibilities.

SOLID WASTE PRACTICES

Solid Waste Generation

TIRU's four plants received 1,651,112 tons of residential, commercial and light industrial waste in 1976 from Paris and the 54 suburbs. This is a 0.73 percent increase from the previous year. Since 1972, refuse from Paris and the suburbs has been declining in volume as can be seen in Figure 6-3 and Table 6-1.

Industrial waste as a proportion of the total is very little. This has likely lead to the rather low calorific value of the waste. The prohibition of kitchen disposal units naturally causes the wet garbage portion of the waste to rise. Local officials report that the Issy lower heating value normally ranges from 1700 to 1900 Kcal/kg (3420 Btu/pound) [7955 kJ/kg] (referred to LHV = lower heating valvue).

The manufacturer, however, designed the plant for a much wider range: 900 to 2500 Kcal/kg (1620 to 4500 Btu/pound) [3768 to 10,467 kJ/kg] (all LHV)

Figure 6-4 presents the weekly and seasonal pattern of collection (incineration and landfill also). Note the sharp drop in collections during the July through September period. The pattern is opposite in many U.S. cities where summer generation is often high.

PVC content in Paris waste ranges from 1 to 1.7 percent.

Solid Waste Collection

Refuse is collected in standard refuse collection trucks. However. some material is received at Issy in $30m^3$ ($40\ yd^3$) transfer trailers from Romainville, the transfer station Northeast of Paris.

Paris has 750 trucks bringing refuse to all four plants. Of these, 180 are electric. Forty are only 6 or $8m^3$ (8 or $10\ yd^3$) for collecting

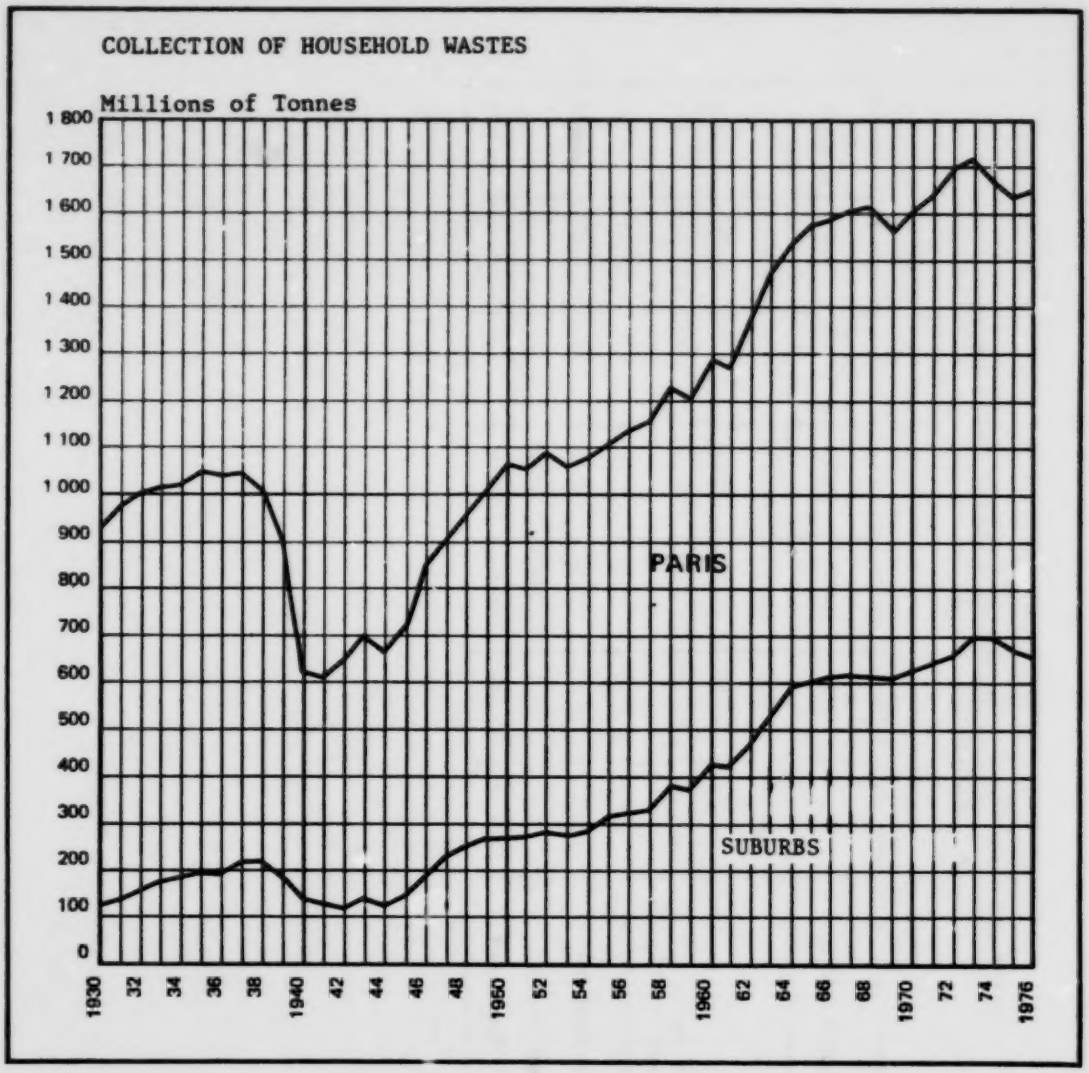

FIGURE 6-3. LONG-TERM GENERATION RATES OF SOLID WASTE IN PARIS AND ITS SUBURBS

TABLE 6-1. SOURCE AND AMOUNT OF GREATER PARIS WASTE
(TONNES/YEAR)

SOURCE AND WASTE	1972	1973	1974	1975	% 1975/1974	1976	% 1976/1975
Paris	1 010 369	1 011 649	964 302	962 535	0.18	988 219	2.66
Suburbs	624 967	630 147	618 481	590 714	4.49	576 982	2.32
Greater Paris Collection Dept.	1 635 336	1 641 796	1 582 783	1 553 249	1.86	1 565 201	0.77
Other communities	16 873	19 872	21 150	19 795	6.40	22 436	13.34
Private Haulers	41 557	53 105	62 667	64 132	2.33	63 475	1.02
Business Truck	1 621	2 075	3 857	1 985			
Total Received	1 695 387	1 716 848	1 670 457	1 639 161	1.87	1 651 112	0.73

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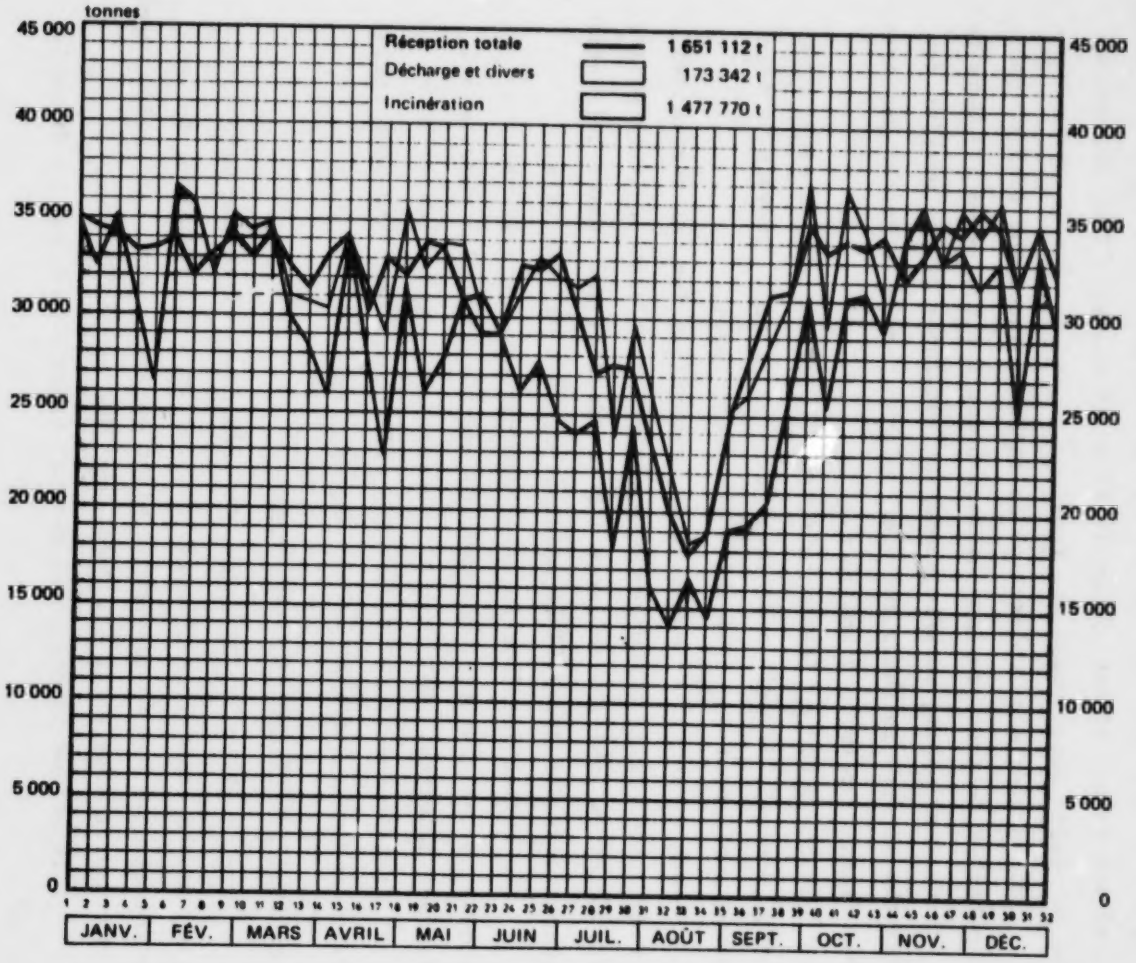


FIGURE 6-4. WEEKLY AND SEASONAL PATTERN OF SOLID WASTE COLLECTION IN THE GREATER PARIS AREA

on narrow streets. Most, however, are 16 m^3 (20 yd^3) traditional European garbage trucks.

The electric trucks mentioned above can travel 50 km (30 miles) on a charge. A typical route is 5 km (3 miles) while the typical distance to unload and return to the garage is 15 km (9 miles). Thus the truck must be recharged about every two runs.

The schedule of collection is rather unique. The City of Paris public vehicles deliver to Issy between 6 and 8 a.m.; seven (7) days per week. These same public workers spend the remainder of the working day sweeping the streets in their assigned neighborhoods. Suburban and private vehicles deliver between 9 and 12 a.m.

Of the 5,000 collection workers, 70 percent are foreign; many being from Senegal, Algeria and other parts of Africa. There have been increasing numbers of French workers in recent years.

Each of the 55 communities is responsible for its respective collection. The cities either publicly collect or license private haulers. The City of Paris publicly collects its residential and commercial waste but subcontracts its truck fleet maintenance to a private firm.

The collection fees in most communities are assessed proportionally to real estate taxes once the year's financial results are declared and accepted. The typical household collection fee would be about 350 Fr fr/tonne ($65.86/ton). The collection costs had been rising 15 percent per year but rose only 5 percent last year.

Solid Waste Transfer and/or Pretreatment

During 1976, 59,700 tonnes (65,670 tons) of refuse were routinely collected in the Romanville transfer station area and then sent to Issy for incineration. Due to respective plant outages, Ivry sent 14,800 tonnes (16,280 tons) to Issy while St. Ouen sent 900 tonnes (990 tons).

Bulk refuse is collected several times a year and is directly landfilled.

There are no major source separation programs or recycling centers.

Solid Waste Disposal

The long term trend of three disposal alternatives (incineration, composting and landfilling) is shown in Figure 6-5). Incineration was in vogue before World War II (WW II) and regained posture after 1960 with the advent of the water tube wall incinerator (80.5% of the total in 1976). Composting, prevalent before and after WW II is no longer an alternative in the Paris greater metropolitan area (0.0 of the total in 1976). Landfilling has only been a volume activity since WW II, but has now only a minimal position among disposal alternatives (10.5% of the total in 1976).

The refuse is taken to one of the four plants shown in Table 6-2. Issy-les-Moulineaux, Ivry and St. Ouen are refuse fired steam generators while Romainville is an old incinerator converted to a transfer station. About 47 percent of the Romainville waste is incinerated. The rest is landfilled at Bouqueval.

Referring back to Figure 6-2, the Issy trucks travel one way (as the crow flies) up to 8 km (5 miles) towards the center of Paris and up to 13 km (8 miles) out to the suburbs. The Romainville transfer trailers must travel 15 km (9 miles) one way on expressways but through the center of Paris.

TIRU is responsible for operations at all four facilities as a metropolitan regional activity.

There is no codisposal of sewage sludge at the Issy plant.

DEVELOPMENT OF THE SYSTEM

Background

Paris is commonly known to be a large historical urban metropolitan center. As a result, the structure of the community with respect to solid waste collection and dispoal was established decades ago.

The first Issy incineration facility was built in 1903. The plant had three refractory lined batch ovens with no heat recovery capability. A second plant was built on adjoining land in 1928. This plant consumed about 230,000 tons/year in six continuous feed furnaces. This plant did recover energy with its three 6 mw turbines producing a total of 18 mw.

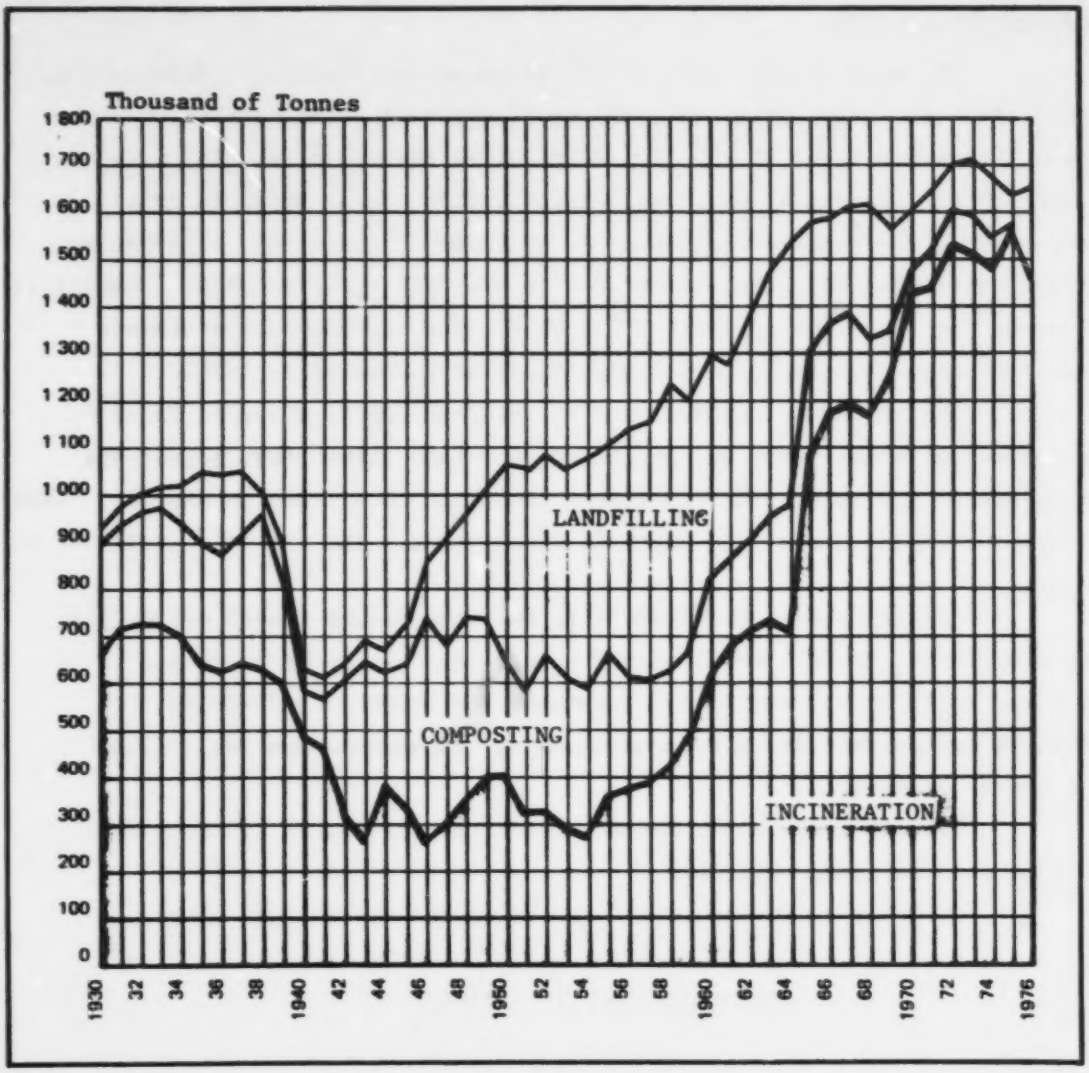


FIGURE 6-5. EVOLUTION OF THREE BASIC SOLID WASTE TREATMENT METHODS

TABLE 6-2. DESTINATION OF WASTE COLLECTED IN THE GREATER PARIS AREA (Tonnes)

USINES	1972	1973	1974	1975	% 1975/1974	1976	% 1976/1975
ISSY-LES-MOULINEAUX	535 716	526 086	517 645	521 046	+ 0,66	522 404	+ 0,26
IVRY	509 539	532 152	533 252	516 899	— 3,07	531 521	+ 2,83
ROMAINVILLE	227 436	231 658	225 317	220 735	— 2,03	228 035	+ 3,31
SAINT-OUEN	374 077	374 177	356 672	369 466	+ 3,59	369 152	—
TOTAL	1 646 768	1 664 073	1 632 786	1 628 146	— 0,28	1 651 112	+ 0,73

In 1946, EDF-TIRU assumed operational responsibility for the plant.

This second Issy plant was closed in 1955 and demolished in 1962. From 1955 through 1965 much of the Southwest Paris area's waste was then composted and landfilled. (See the previous bulge in the landfilling methods. (Figure 6-5).

Beginning of Subject System

In 1960, Parisians voted to build their third Issy plant. TIRU organized the bidding and called for separate contracts on everything except the "chute-to-I.D. fan". Other contracts were for civil engineering, feed-water system, turbines, chimneys, ash recovery, landscaping, etc.

When asked why Martin was chosen, officials made the following reply.

(1) Local officials were most impressed by the Martin grate as seen in Sao Paulo, Brazil. (However, Sao Paulo heats only combustion air, not steam.)

(2) Martin suggested to use the new Issy plant for experimentation both by Martin engineers and by TIRU staff. (This arrangement has facilitated the development of the TIRU staff into one of the best local operating organizations in Europe.)

(3) In the point system evaluation procedure, Martin was granted ten points over competition for its thermal efficiency. Martin had previous experience in coal plants.

(4) Integration of a grate and boiler system was not new to Martin. At that time, the concept was fairly new to some of the other competitors. TIRU wanted an"integrated" refuse fired steam generator as contrasted with a grate followed by a waste heat boiler.

(5) In 1962, the biggest unit in France was the 8 ton/hour facility at St. Ouen (Volund's grate followed by a rotary kiln). TIRU, however, wanted a very large unit. Martin, with its modular three multiple runs could offer a 15 ton/hour system. With limited land available for more units and with TIRU's desire for efficiently produced electricity, they opted for Martin.

The above was cause for Martin to be chosen despite Martin's "chute-to-I.D. fan" price being 50 percent higher than some of the competition.

Building Subject System

The total 1962 capital investment cost was 110,000,000 Frfr ($22,700,000) including a negligible amount to destroy the unused second Issy plant.

There were few notable aspects or interruptions associated with the construction.

Availability for Operation

Percent availability is a definitional matter where one must pay careful attention to the numerator and denominator as displayed in the following four tables 6-3 to 6- 6 .

Table 6-3 Total system (Furnace/boiler)

Table 6-4 Ash handling

Table 6-5 Steam production

Table 6-6 Electricity production.

By having a concise display of pertinent operating data, the reader can better develop his own ratios regarding (1) a total refuse fired steam generator (2) that produces ash, (3) much steam for district heating, and (4) a moderate amount of electricity. Some information in these tables will be repeated and discussed in later relevant sections.

In Table 6-4 a footnote refers to some bottom ash being sent to Ivry in 1976. This was done because Ivry has a metal recovery system for processing furnace residue.

TABLE 6-3. AVAILABILITY OF ISSY'S TOTAL SYSTEM

	Month of December		Year of	
	1976	1975	1976	1975
Hours of operation (4 furnaces)	2,608	2,752	29,053	29,428
Tons of waste burned per furnace/boiler per hour	20.4	17.4	19.9	19.1
Availability of furnace/boiler	2,795	2,818	29,723	30,291
Maximum hours available	2,976	2,976	35,040	35,040
Actual operation availability	87.6	92.5	82.9	84.0
Furnace availability	93.9	94.7	84.8	86.4
Hours of scheduled downtime	-	64	2,376	3,126
Delayed report carryover from 1975	-	-	307	-
Hours of unanticipated downtime (total of 4 units)	181	94	2,730	1,623

Source: TIRU statistics

TABLE 6-4. DISPOSITION OF BOTTOM ASH, SCRAP METAL AND FLY ASH

	Month of December		Year of	
	1976	1975	1976	1975
Tonnes of waste burned	53,426	48,206	522,404	521,046
Tonnes of scrap iron and bottom ash produced	18,699	16,872	205,679	198,664
Tonnes of fly ash produced	1,147	876	11,595	10,726
Percent scrap iron and bottom ash of total refuse input	34.5	35.0	39.4	38.1
Percent fly ash of total refuse input	2.1	1.8	2.2	2.1
Tonnes of bottom ash clinker sold	2,311	6,763	35,686	51,158
Tonnes of scrap iron sold	680	751	9,299	9.871
Percent sold as bottom ash clinker	4.3	14.0	6.8	9.8
Percent sold as scrap iron	1.3	1.6	1.8	1.9
Tonnes of bottom ash landfilled	17,504	9,525	154,017	138,352
Tonnes of bottom ash sent to Ivry			7,257	
Tonnes of fly ash landfilled	1,147	876	11,595	10,726
Percent bottom ash landfilled	32.8	19.8	30.9*	26.6
Percent fly ash landfilled	2.1	1.8	2.2	2.1

* Includes 1976 bottom ash sent to Ivry for metal recovery.

Source: TIRU statistics

TABLE 6-5. STEAM PRODUCTION, LOSSES, SALE AND AVAILABILITY

(Tonnes of Steam)	Month of December 1976	Month of December 1975	Year of 1976	Year of 1975
Basic production of steam exiting boilers (50 bars, 410°C)	86,772	81,294	964,718	940,377
Loss at pressure relief valve	(1,026)	--	(14,598)	(3,503)
Technical sampling and losses	(3,256)	(4,077)	(38,580)	(43,172)
Available from boiler	82,490	77,217	911,540	893,702
Condensing turbines	(11,609)	(3,879)	(129,435)	(113,623)
Auxiliary condenser	(72)	--	(1,238)	(538)
Losses to atmosphere	--	(338)	(437)	(660)
Other losses	(614)	(2,380)	(6,241)	(35,082)
Sales to C.P.C.U.(1) for district heating	70,195	70,620	786,671	743,799
Average hourly vaporization during operation	33.2	29.5	33.2	31.9
Hours available of equipment to produce steam	2,880	2,875	30,567	30,348
Boiler availability	96.7	96.6	87.0	86.6
Percent utilization if boiler is available	75.3	70.7	78.9	77.5
Tonnes of steam per tonne of refuse	1.62	1.69	1.67	1.67

Source: TIRU Statistics.

(1) C.P.C.U. is the City of Paris Urban Heating Company.

TABLE 6-6. ELECTRICITY PRODUCTION, LOSSES SALE AND AVAILABILITY

(Mega watt-hours)	Month of December 1976	Month of December 1975	Year of 1976	Year of 1975
Production from counterpressure turbines	3,960	3,576	43,597	42,418
Production from condensing turbine	2,041	696	23,826	20,157
Total production	6,001	4,272	67,423	62,575
Purchase from C.I.M.E.	61	0	300	219
Total available	6,062	4,272	67,723	62,794
Internal uses of electricity	(1,752)	(1,608)	(19,654)	(18,753)
Electricity sale to C.I.M.E.	4,310	2,664	48,069	44,041
Internal consumption (Mw-h) of electricity per tonne of refuse burned	0.032	0.033	0.033	0.033
Counterpressure turbine actual hours	679	744	8,382	8,531
Condensing turbine actual hours	534	219	5,033	4,016
Counterpressure turbine hours available	744	744	8,602	8,613
Condensing turbine hours available	744	510	8,602	7,961
Counterpressure turbine availability	100	100	97.9	98.3
Condensing turbine availability	100	68.6	97.9	90.9
Counterpressure turbine utilization during availability	59.1	53.4	56.3	54.7
Condensing turbine utilization during availability	17.3	8.6	17.4	15.9
Production of electricity (Kw-h) per tonne of steam entering the:				
Counterpressure turbine	48.0	46.3	47.8	47.5
Condensing turbine	175.8	179.4	184.0	177.4

Source: TIRU Statistics.

PLANT ARCHITECTURE

Plant Setting

The plant is situated beside the highway along the Seine River. The major rail tracks, seen in Figure 6-6, are inland and on the plant's other side. Light industry surrounds the plant.

Environmental Setting (non-pollutant aspects)

Considering the industrial setting, the plant has little objectionable noise. As with virtually all refuse fired steam generators, the negative pressure minimizes odor. Vegetative landscaping is modest but done in good taste.

Plant Hygiene

Being a large plant, one man is assigned to keep clean the exposed tipping area shown in Figure 6-7. The scalloped ceiling and arch to the tipping area is one of the most sophisticated architectural features observed in the European plants.

As in other well designed and operated plants, no specific or routine measures are needed to control rodents or insects.

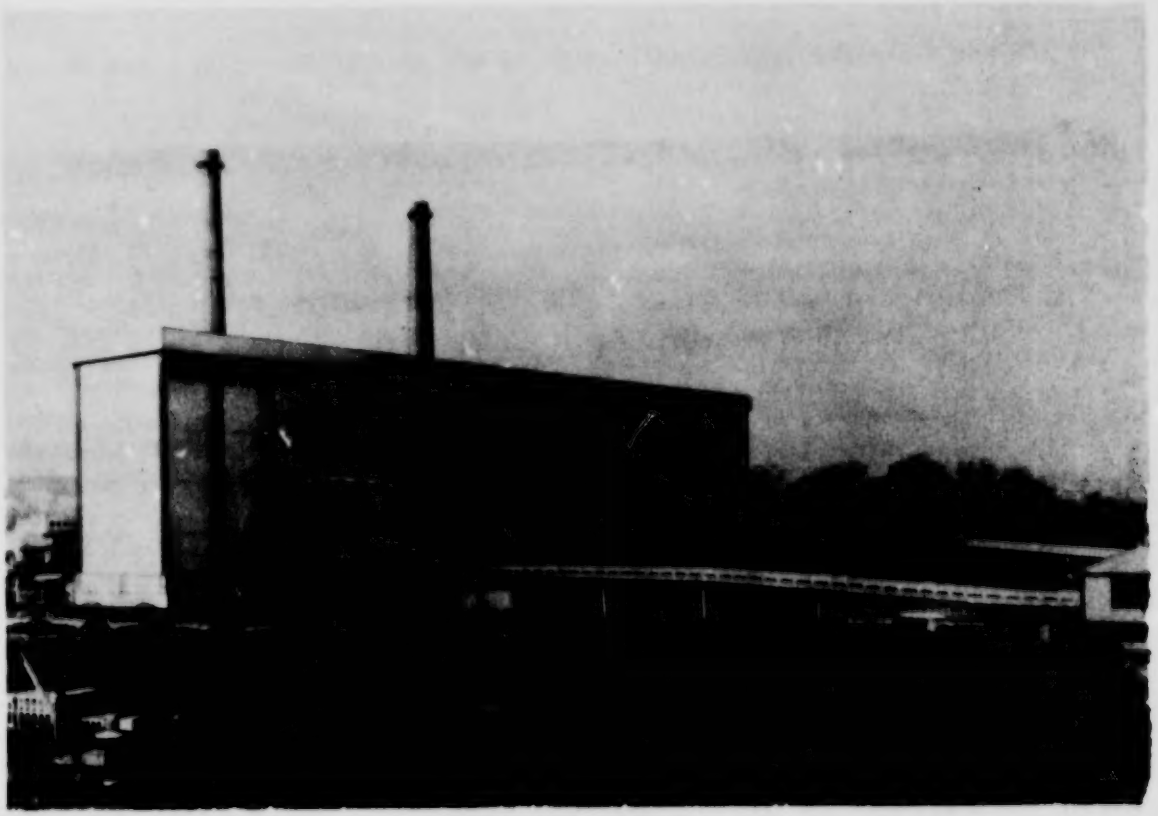


FIGURE 6-6. VIEW OF THE EAST SIDE OF THE PARIS:
ISSY-LES-MOULINEAUX PLANT
(Courtesy of Josef Martin, Gmbh)

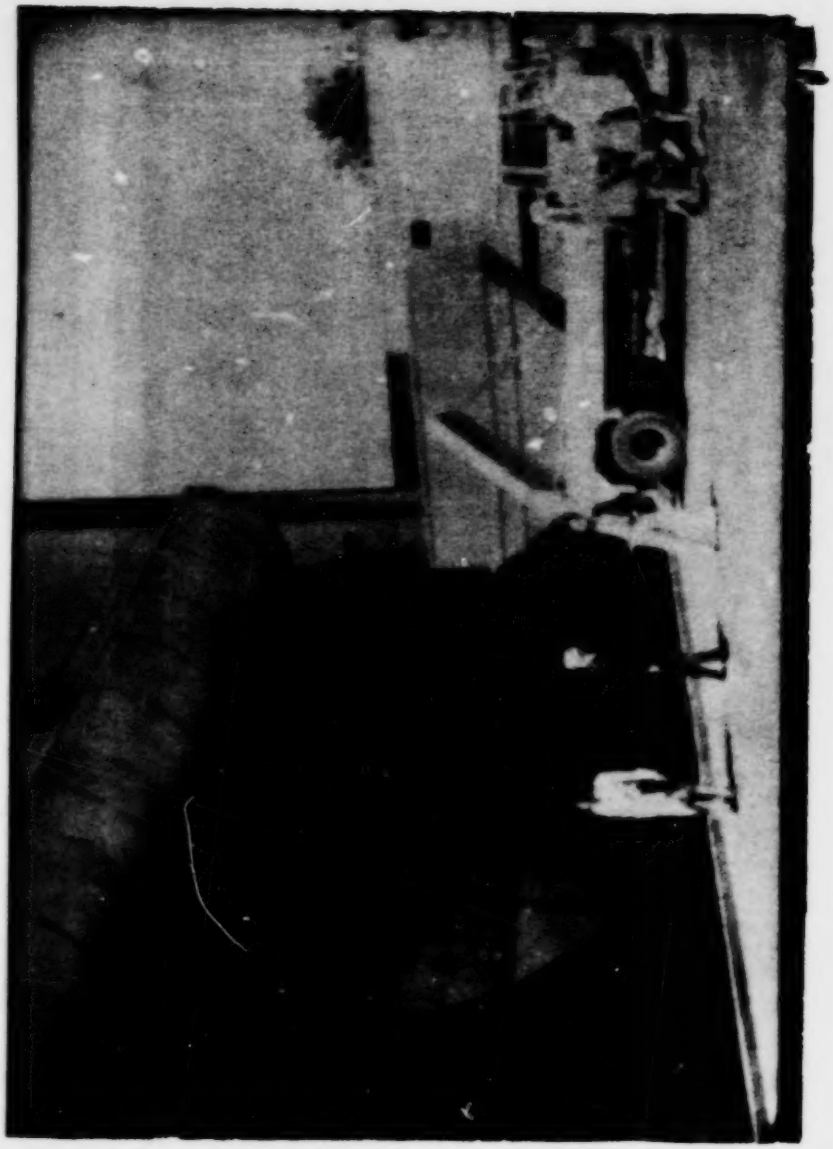


FIGURE 6-7. SCALLOPED ARCH OF PARIS: ISSY TIPPING AREA (Battelle Photograph)

REFUSE FIRED STEAM GENERATOR EQUIPMENT

Waste Input

Household, commercial and light industrial wastes are consumed in the raw state, i.e., directly from the garbage truck. An unusual waste delivery pattern affects operations. Wet domestic and commercial refuse collected by public officals arrives in the morning. However, dry industrial refuse collected by private haulers arrives in the afternoon. Crane operators are thus required to be more diligent in their mixing activities.

Each furnace was originally designed for 15 tonnes (16.5 tons) per hour. The rating was later raised to 17 tonnes (18.7 tons) per hour. However, in 1975, the throughput in "active furnaces" averaged 19.1 tonnes (21.0 tons) per hour and in 1976, the average was 19.9 tonnes (21.9 tons) per hour. This overloading does strain the system and TIRU officials are concerned about the long term maintenance effects.

For the total system that processed 522,404 tonnes in 1976, this equates to 1,431 tonnes (1,574 tons)per day on a seven day burning basis.

The system is designed to handle waste with a lower heating value (LHV) of 900 to 2500 K cal/kg (1600 to 4500 Btu/pound) [3769 to 10,647] K Joules/kg]. Samplings in 1975 and 1976 reveal a 1700 to 1900 mean value. Because the operators have continuous readings of weight processed and steam produced, continuous LHV are available.

The PVC content ranges from 1.0 to 1.7 percent.

Weighing Operation

A weighing station is centered on the tipping floor situated at 6.5 m (21.3 feet) above the River Seine (see exterior room in Figure 6-5), opposite the charging doors. The mechanical scale has excellent accuracy and has posed no unusual maintenace problems. The government officially tests and recalibrates the scales once per year.

Provisions to Handle Bulky Wastes

Bulky wastes (stoves, bedsprings, etc.) are not normally sent to the Issy plant. The plant can accept almost any size material that can get into a traditional garbage truck. Industrial waste generators sign a contract where they agree not to deliver bulky liquid and other hazardous waste to the TIRU plants. Several times per year, special bulky waste collections are held.

However, if bulky wastes are taken to Issy, the scale operator can order the driver to offload onto an open area and thus the oversized pieces never enter the pit. The Martin hopper, feed chutes, grate, and ash handling systems can, however, accomodate very large objects, but the eventual bottleneck is often the ash discharger.

One notable and unbelievable example was a fully assembled Fenwick forklift truck that was found inside the furnace and on the grate. Because it could not pass through the ash handling system, it was removed by first cutting it into pieces.

Also other undesirable objects do enter the pit and may require the following actions:

(1) If in the pit, pull large objects up to small platform next to and at the level of the hopper. Using welding torch cut the object into smaller pieces. Drop pieces into the hopper for normal processing.

(2) Using the crane bucket, use hoods and rope to pull the bucket back to the truck tipping door.

(3) Use long rakes and hooks for dislodging in the hot furnace.

(4) Use shorter rakes and hooks at the end of the ash discharger.

(5) Assess penalties against the waste generator.

(6) If the waste generator continues to send undesirable material to the plant, cancel his disposal privilege for 2-3 months.

Unfortunately, the pit area is not designed for a crane to simply pick up the bulky or hazardous object for setting aside on the floor. Martin engineers recommend that such provisions be made at future plants.

Waste Storage and Retrieval

Nine (9) doors open to the 6000 m^3 (7850 yd^3) pit that holds 2,500 tonnes (2,750 tons) when level. When refuse is stacked above the tipping floor level, 5,000 tonnes (5,500 tons) can be stored. Therefore, 3 to 4 days waste can be stored.

Concern was expressed about spontaneous combustion when 2 to 3 days supply accumulate in the pit. Another source of fires is sparks from constructive welding to repair the crane or bucket and destructive welding to destroy large bulky refuse.

For small fires, the truck-tipping floor mounted hoses are sufficient. The local fire department is called out for large fires.

The traveling bridges are inspected each morning. Ten electrical contacts must be maintained. Repairmen can replace contacts until too many have failed. It is the welding of these contacts that has caused several pit fires. Then the entire assembly must be replaced.

" If future designers wish to avoid downtime" plant officials recommended "they should consider two independent bridges where each has individual circuits and are on different elevations."

The polyp bucket has two kinds of cable. One U-shaped strand lifts and lowers while the other U-shaped strand opens and closes the bucket. The cables last anywhere from 2 days to 1 month.

Cables are inspected every Friday to avoid calling in repairmen over the weekend. Even this does not insure failsafe weekends. If a cable is fraying or has kinks near the bucket, the cable is shortened by the operations staff, not maintenance. Four people often spend 3-4 hours repairing opening-closing cable. Two people can repair the lifting and lowering cable in 1-1/2 hours.

The crane is equipped with a Bourdon dynamometer. This load cell measures current in amperes, in the static position, just above the hopper and immediately before discharging. The crane has a capacity of 10 tonnes. The buckets are 5m^3 (6.5 yds^3) and can carry 3-3 1/2 tonnes (3.9 tons).

A fertilizer plant within the same monolithic structure can be seen above the railroad tracks in the previous Figure 6-6. These same cranes can take material from the bunker to the fertilizer plant that produces tonnes (20 to 30 tons) of fertilizer per hour. The fertilizer can be stored in a separate 400m^3 (525 yd^3) bunker.

Furnace Hoppers and Feeders

The hopper opening has dimensions of 6.25 m (20.5 feet) by 4.0 m (13.12 feet). The hopper tapers off to the chute having dimensions of 1.438 m (4.72 feet) by 6.25 m (20.5 feet). Normally, the hopper is kept empty while the feed chute is full as can be seen in Figure 6-8. The chute has a water cooled jacket. There is also a horizontal water-cooled cut off gate to minimize burnback. Finally, there is a water-cooled arch connecting the combustion chamber.

Not typical of most Martin plants, Issy plant experiences frequent burnback on startup -- about 90 percent of the time. Burnback on shutdown is not quite as frequent. In Martin's newer Zurich plant, steam nozzles at the chute's rear and bottom propel the refuse out onto the grate, thus minimizing burnback.

The chute has one access door for easy maintenance during outage of the incinerator.

Of the four Issy furnace feeding systems, one is hydraulic (150 bar) and three are electro-mechanically driven. Plant officials value the systems as about equal. Martin officials admitted their initial skepticism regarding hydraulic feeders as proposed by TIRU. However, Martin now normally recommends the hydraulic feeders. A key feature is that the hydraulic system responds better to a jamming object without breaking. A mechanical system will more easily break. The main problem with the hydraulic system is oil loss.

Each of the three runs per furnace has two feeder mechanisms; an upper and a lower ram or pusher. The furnace feeder total width is 6.3 m (20.67 feet), i.e., 3 x 2.10 m. The cross section of the fuel entry into the furnace is 8.82 m^2 (94.9 ft^2) having dimensions of 6.3 x 1.4 m (20.67 x 4.6 feet).

Each pusher is provided at its front end with high-grade heat-resisting chromium steel alloy bars 12 mm thick and at its rear end with a 10 mm thick steel plate, which is reinforced to withstand the impact of refuse falling from the hopper. Each pusher is supported at its front end by sliding noses, and at its rear end by roller bearings on each side and guided by a vertical roller bearing. Each pusher is operated by a hydraulic cylinder.

The control of the feeding device is over a range of more than 1 to 10. The control equipment is mounted in the hydraulic control cabinet

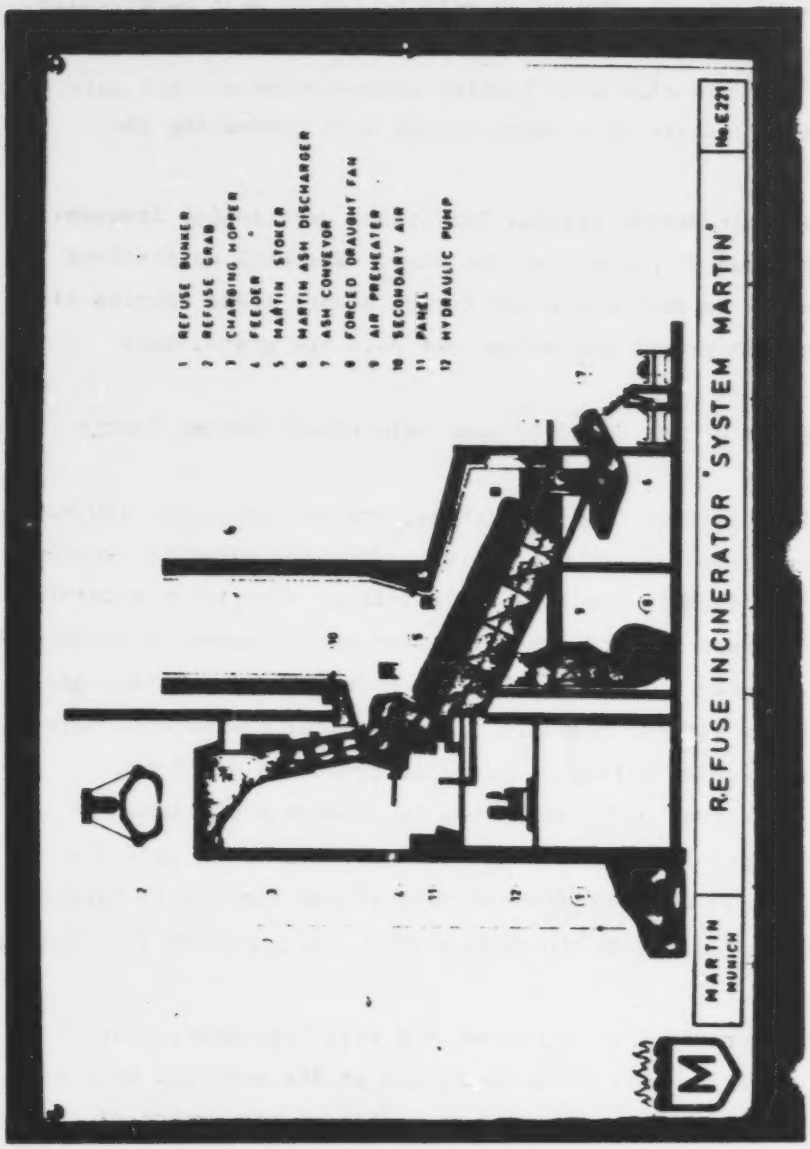


FIGURE 6-8. PLANT SCHEMATIC TO SHOW UNDERFIRE AIR SYSTEM OF MARTIN

together with the control equipment of the grate. The feeder control is of the auto-manual type whereas the manual operation may be done locally from the control room as specified.

In some more recent systems arrangements are made such that the refuse level within the chute at the minimum allowable level can be measured by a radioactive device and indicated in the crane operating cab and in the main control room.

Primary Air Source (Underfire Air)

Primary air is pulled in from the bunker through vents between the hoppers as can be seen in Figure 6-1. Each incineration unit is furnished with one Pratt forced draught (FD) fan with a 100,000 Nm^3/hour capacity (62,210 scfm). The air pressure is 550 mm of water (21.7 in).

The fan is of the radial flow type with inlet vane control. The fan housing is provided with one inspection door. The wall of the housing is reinforced by external fins.

The impeller is statically and dynamically balanced. The bearings are provided with a special seal to prevent the ingress of dust, with oil level indicators and with local thermometers fitted with maximum temperature contacts. The shaft of the fan is made of forged steel.

Since the combustion air is drawn from the refuse bunker, a certain content of solid particles in the combustion air with subsequent deposition, fouling and unbalance of the impeller is taken into consideration. Therefore, cleaning with water, and replacement are simple and quick. This fan delivers the air to the grate via a steam air preheater with controlled by-pass. The undergrate airpressure is controlled constant of 40.0 mbar (16 in water)

by means of fan inlet vanes. They by-pass control damper enables the combustion air to be heated to the temperature required for the combustion process. With the by-pass damper closed, a maximum combustion air temperature of 200 C (392 F) can be reached.

Ducts for undergrate air and for front and rear overfire air nozzles are branched downstream of the air preheater.

For each furnace, the air is distributed to 21 plenum chambers (7 plenum chambers per run and 3 runs per furnace). All compartments have individual orifices covered by dampers. All dampers are remote controlled and actuated by a servo-motor-driven mechanism. Each damper can be individually regulated if this is necessary for particular fire-bed conditions, but normally all dampers together will be remote controlled.

The desired CO_2 content in the gases and the combustion process itself, under all load conditions is maintained economically by remote control of the air dampers from the control room.

Siftings are pneumatically removed from the plenum's bottom in time with an auto clock. The system is manually controlled from the floor or can be semi-automatically controlled from the control room. The siftings removal system is unique to Issy and will not likely be duplicated elsewhere.

The plenum chambers are inspected once per year. Wall thickness is measured near the air entrance and the siftings collector exit. Blasts of air with small abrasive glass, etc., are erosive.

Secondary Air (Overfire Air)

The secondary air is supplied by a fan having an output of (16,500 ft^3/min) and rated at 28,000 Nm^3/hr. The air is delivered to two rear wall rows. Each row has 16 nozzles.

Another separate secondary (or tertiary) air system starts with a fan having an output of (26,000 ft^3/min) and rated at 44,000 Nm^3/ hr. This air is delivered to a single row of four (4) nozzles located 1 to 2 m (3 to 6 feet) above the front wall nose.

Both secondary air systems together provide 20 to 25 percent of the total air consumed.

In the past, there has been some radiation burning of the nozzles. Plant people pointed out that air should be passing through the nozzles at all times. But even with the radiation burning, they never have had to replace any nozzles.

Burning Grate

The Martin "Reverse Reciprocating" Stoker grate is inclined downward from the feed end towards the clinker discharge end and comprises alternately fixed and moving steps of grate bars. The activated steps move slowly counter to the downhill refuse movement.

In this manner, the fuel bed is constantly agitated, rotated, and again leveled out. The glowing mass is pushed back from the main burning area towards the front or feeding end of the grate. The different phases of combustion i.e., drying, volatilizations, ignition, and burn-out thus take place at the same time in close contact with one another. Freshly fed refuse is quickly dried out and ignited from below by the base fire always existing at the grate front end. (See Figure 6- 9).

The incinerator grate is set at an angle of 26° and is 6.3 m wide by 8.4 m long having a projected grate surface area of 53 m^2 and an active grate surface of 60 m^2. It consists of three runs (sections) having

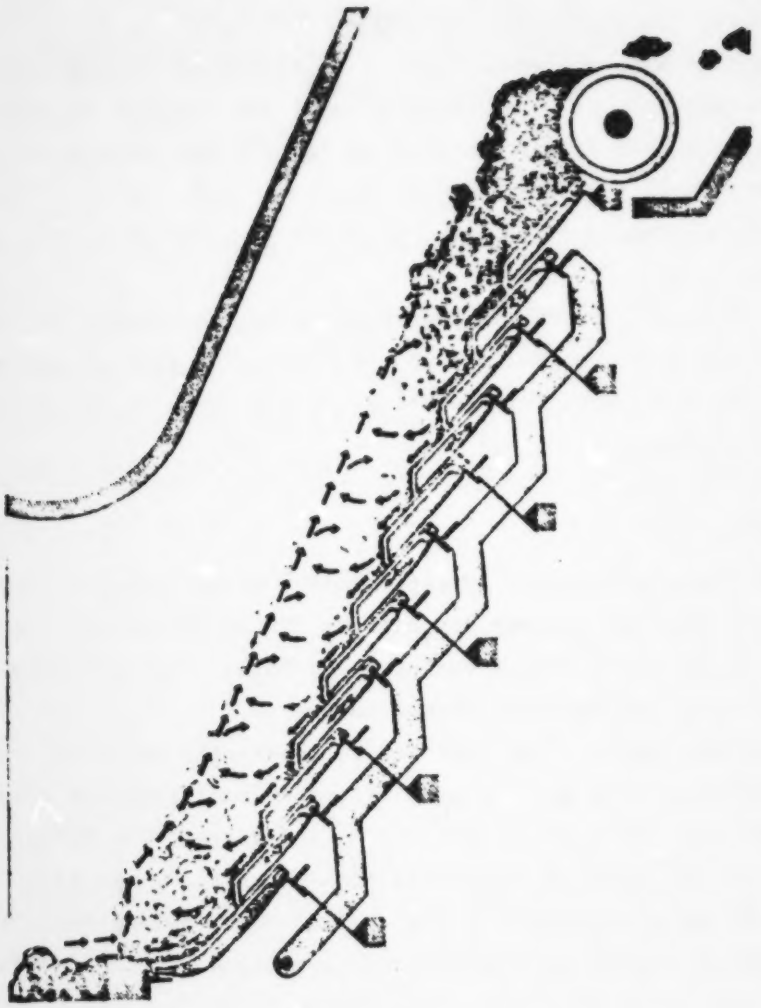


FIGURE 6-9. REFUSE AGITATION ACTION OF MARTIN GRATE
(Courtesy of Josef Martin Feurungsbau, Gmbh)

15 active steps, each alterative step being of the movable type operated by the hydraulic grate mechanism. Each run has 100 mm (4 inch) wide grate bars.

The grate bars consist of a wear and high-heat resisting 16 percent chrome steel alloy. Air entering the grate bars passes through the serpentine channels in the underside of the bar before passing through the air slot (less than 2 mm wide) between adjacent bars into the fuel bed. The static air pressure resistance to air flow thus created is higher than that of the refuse layer on the grate. As a result, the undergrate air is uniformly distributed over the area of each grate zone.

The Martin Stoker is subdivided lengthwise into seven compartments to which undergrate air is admitted through damper openings of different sizes in accordance with air supply requirements over the whole grate surface. The opening angle of these dampers is selected by a central controller and is proportioned to the desired heat release. Each section of grate with its air plenum and siftings hoppers are supported by a structural steel system of ample strength to carry all of its parts and a refuse bed of 500 kg/m^2 unit weight. Grates and supports are sufficiently strong to withstand the impact of freely falling refuse from the top of the feed hopper and bulks of slag from the furnace walls, respectively.

The burned-out residue travels slowly down the grate under constant agitation. After reaching the grate end, a slowly rotating clinker roll seizes the residue and dumps it into the quench pit. (See Figure 6-10). This gentle grate action reduces dust and charred-paper generation from the fire bed. This helps reduce dust carried through the boiler and into the precipitator. The grate action also prevents the formation of excessive hot spots and excessive clinker build-up and helps to produce a residue having only about 3 percent unburned carbon. Side faces of the bars are machined to achieve even, uniform widths of air gaps between adjacent bars and are arranged to prevent spreading or bunching of individual bars. At the sides of the grate sections, self-compensating expansion blocks precent binding of the grate bars due to heat expansion. This helps to maintain a constant air gap and ensures that the openings for combustion air are limited to approximately 2 percent of the grate area surface. The air openings in the Martin grate bar design are fixed at the front of the bar so that the combustion air spreads over the whole underside surface of the firebed, regardless of any dense objects. To break up clinker formation, some of the bars have a pyramid head fixed on top.

At the upper and lower end of each stroking movement, the adjacent bars in all grate steps will move, by mechanical action, a distance of

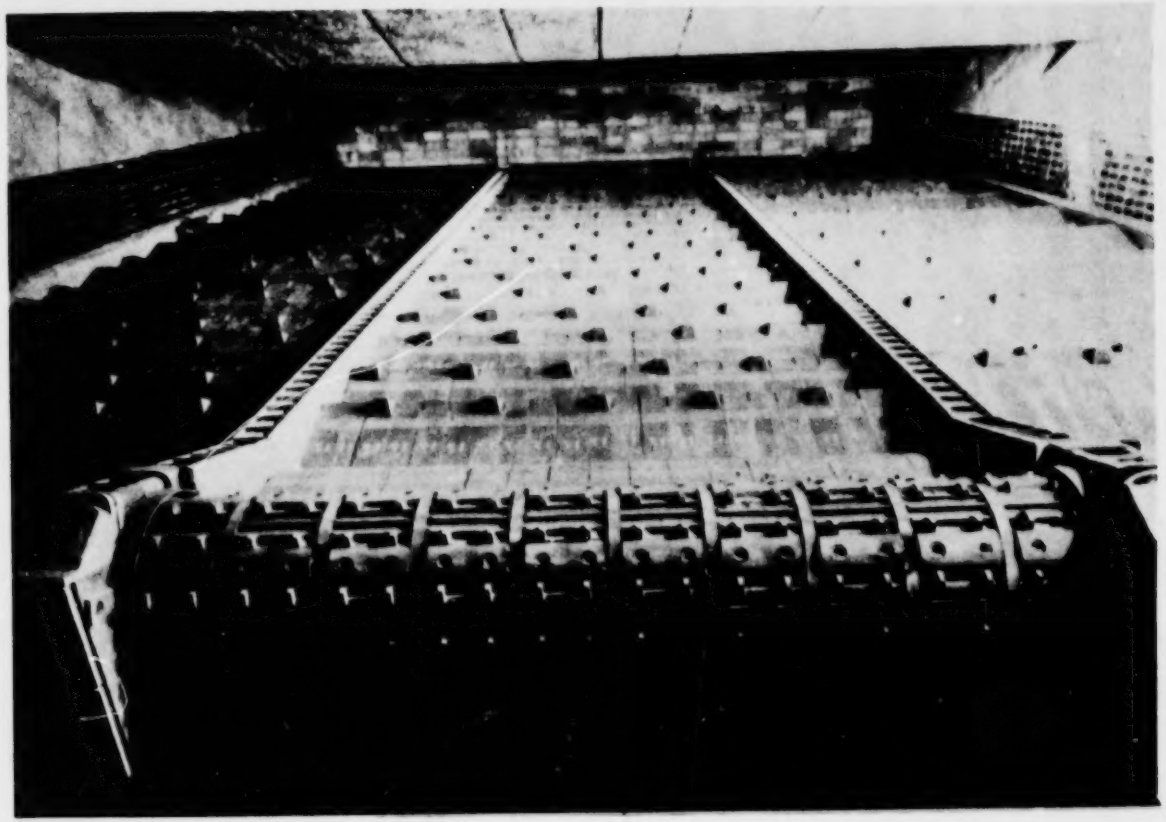


FIGURE 6-10. MARTIN THREE RUN GRATE SYSTEM
(Courtesy of Josef Martin Feurungsbau, Gmbh)

about 20 mm to each other, and this movement prevents blockage of the air gaps.

The operator at Issy has much flexibility in grate control primarily because the grate strokes can be varied anywhere from 7 to 80 per hour.

Above the main burning zone, the combustion gases are turbulated by overfire air jets admitted at high velocity, resulting in a thorough burn-out of the gases. The combustion gases are directed towards the green refuse just introduced to promote its drying and ignition. This is achieved by the rear arch the nose of which projects far into the furnace, and the overfire air nozzles arranged below this arch.

During 12 years of operation, the Issy plant has replaced on the average 60 to 70 grate bars per year per furnace out of a total 900 bars per furnace capacity. Extreme figures have been a low of 40 bars per year up to a maximum of 100 bars per year. The procedure for replacement of individual bars of the grate can be achieved without disturbing the grate as a whole.

Martin has a continuing maintenance contract with TIRU. Martin formally inspects each furnace once per year. In recent years, Martin has noted moderately high grate maintenance problems on the grate mainly because of the overload, i.e., designed for 15 tonnes per hour and running at 20 tonnes per hour.

The movable bars are mechanically activated. While the Battelle team was on location, a most complex failure took place. Siftings and clinker had been collecting in the final plenum of one of the runs. Coincidentally, a wall tube at the top of the second boiler pass burst. Water cascaded down through the second pass fly ash hopper and down onto the lower grate bars and clinker roll. The water, flyash, siftings and clinker formed a concrete like hard mass. Finally, the mass become so hard that the mechanical rotary cam driver burst.

Ash Discharger

The Martin Ash Discharger (See Figure 6-11) receives the slag from the grate as well as the siftings from the different sections of the grate and the fly ash from the two boiler pass hoppers. The water bath forms an air-tight seal. The whole slag and ash discharging equipment is able to handle the largest pieces delivered by the charging chute.

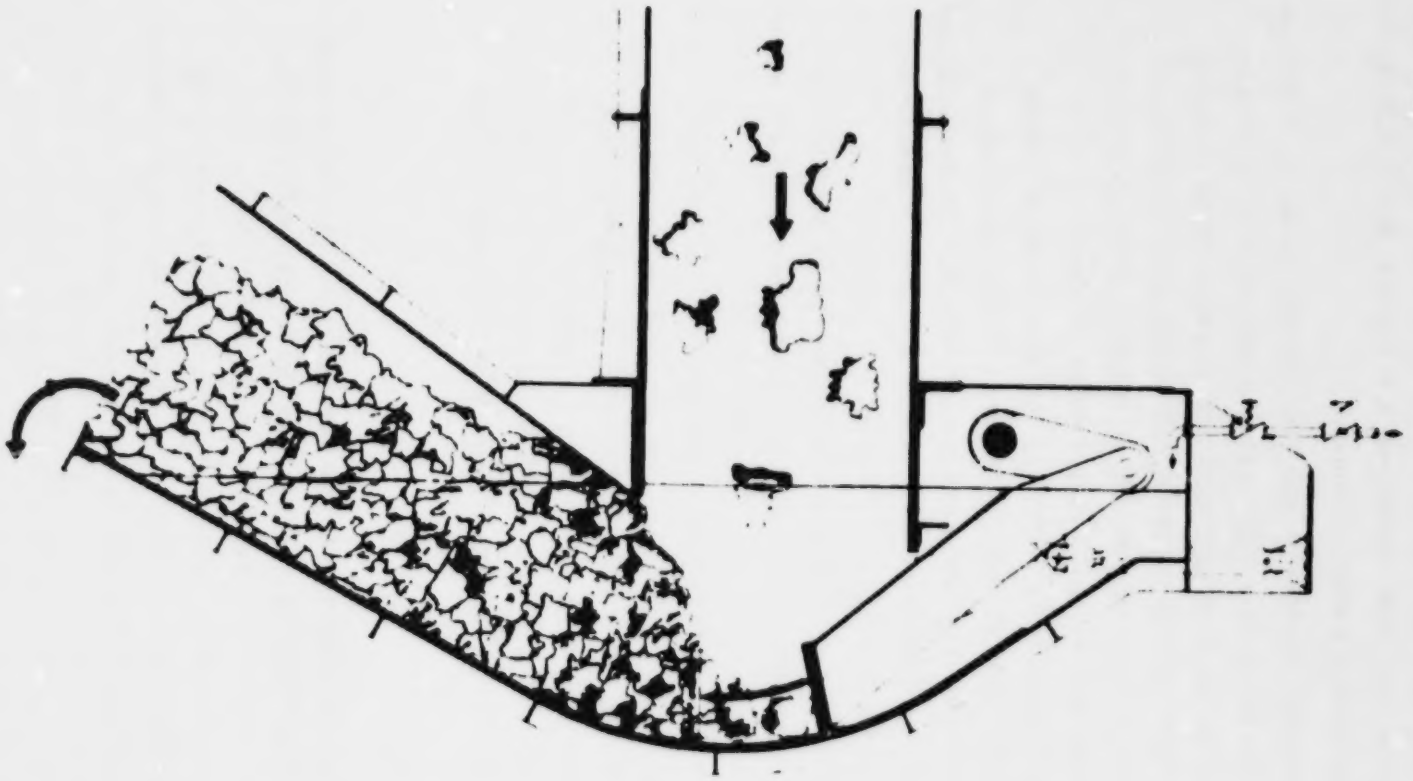


FIGURE 6-11. MARTIN ASH DISCHARGER
(Courtesy of Josef Martin Feurungsbau, Gmbh)

The inside cross sectional dimensions are 2 x 1 m (6.6 x 3.25 feet). The discharge output can be 6.3 tonnes (7 tons).

The remaining water content in the slag and ash is about 15 percent. Water replacement for the relatively small water quenching bath is limited to the water evaporated and carried away with the clinker. This explains the very low water consumption rate of about 100 litres/1000 kg of refuse i.e., about 2000 kg/h of water when burning 20 t/h of refuse. There is no water flowing through the discharger and no polluted water effluent.

Under the discharger mouth, slightly inclined grids of 400 mm mesh are provided through which clinker falls onto a vibrating conveyor whereas bulky objects (mostly tins and barrels) are held back by the grid and may easily be removed by the personnel and dumped into carts or containers standing by. (See Figure 6-12).

The replaceable wearing plates are of 12 mm and 15 mm thickness. All parts are designed to withstand wear and tear during the operation period of at least 8000 hours.

The drive of the ash discharger is protected by an overload protection and the discharging capacity is controlled by an infinitely variable speed regulation in the hydraulic distribution cabinet. The forming of excessive vapor is prevented. The ash discharge has a grate valve at the bottom of the trough for evacuation for maintenance purposes. The trough itself is constructed of steel plates with thickness of 10 mm and suitably reinforced.

Fly Ash Handling

The coarse fly ash collected in the hoppers under the boiler passes is conveyed to the ash discharger via screws. On the other hand, the fine ash collected in the E.P. is not led into the ash discharger but rather into fly ash silos. The purpose is to avoid fouling of the ferrous scrap which is extracted from the refuse clinker. The fly ash collected in these silos is moistened by conditioning screws and discharged onto the clinker in the clinker pit.

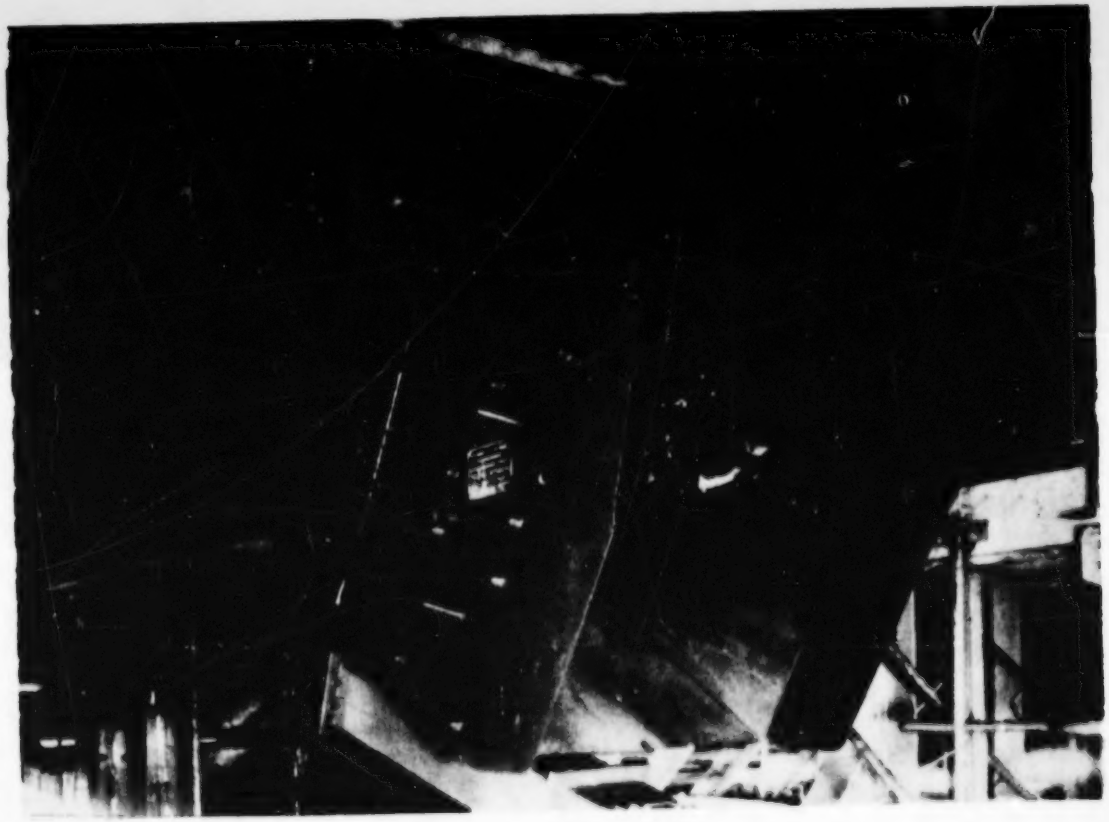


FIGURE 6-12. MARTIN ASH DISCHARGER DUMPING INTO VIBRATING CONVEYOR AT PARIS: ISSY (Battelle Photograph)

Clinker Discharge Roll

A full-width variable-speed residue discharge roll is fitted at the end of the grate to regulate the depth of refuse bed on the grate and to control the rate of residue discharge. The grate speed can be adjusted to suit the nature of refuse so that optimum mixing of the fuel layer can be obtained for fluctuations in load and composition.

The clinker roll is of heavy construction with replaceable cast iron segments. The material is designed to resist heavy abrasion and the temperature likely to be encountered at this point of the grate.

A chute is provided at the end of the grate to direct burned-out residue to the ash discharger. The bottom end is submerged in the water contained in the ash discharger quench trough to ensure a gas seal and to prevent ingress of cold air to the incinerator. The chute is lined with steel plates bolted to form an abrasion resistant surface and it is fabricated in thick plate adequately stiffened. An access door is included in the lower section of the chute to facilitate access above the water level in the ash discharger trough.

Clinker Handling and Scrap Processing

As can be seen in Figure 6-13, clinker exits by conveyor and enters the processing plant on the left of the picture. The ferrous metal is extracted with a magnet and clinker is sorted by size to produce a road base material which is sold. The remaining material is trucked to a landfill.

Furnace Wall (Combustion Chamber)

Issy is an excellent example of the historical development of the Martin recommended furnace.

Stage 1 Refractory Brick Walls. The sidewalls of the combustion chamber and the first and second pass were orginally water tubed, backed by refractory brickwork. Because of flame impingement, corrosion occured on the bare water tubes, which caused furnace side wall tubes to burst after 5,000 to 6,000 hours, resulting in problems to the boiler. Perhaps material was also adhering to the refractory brickwork. For whatever reasons, TIRU decided to change the furnace wall.

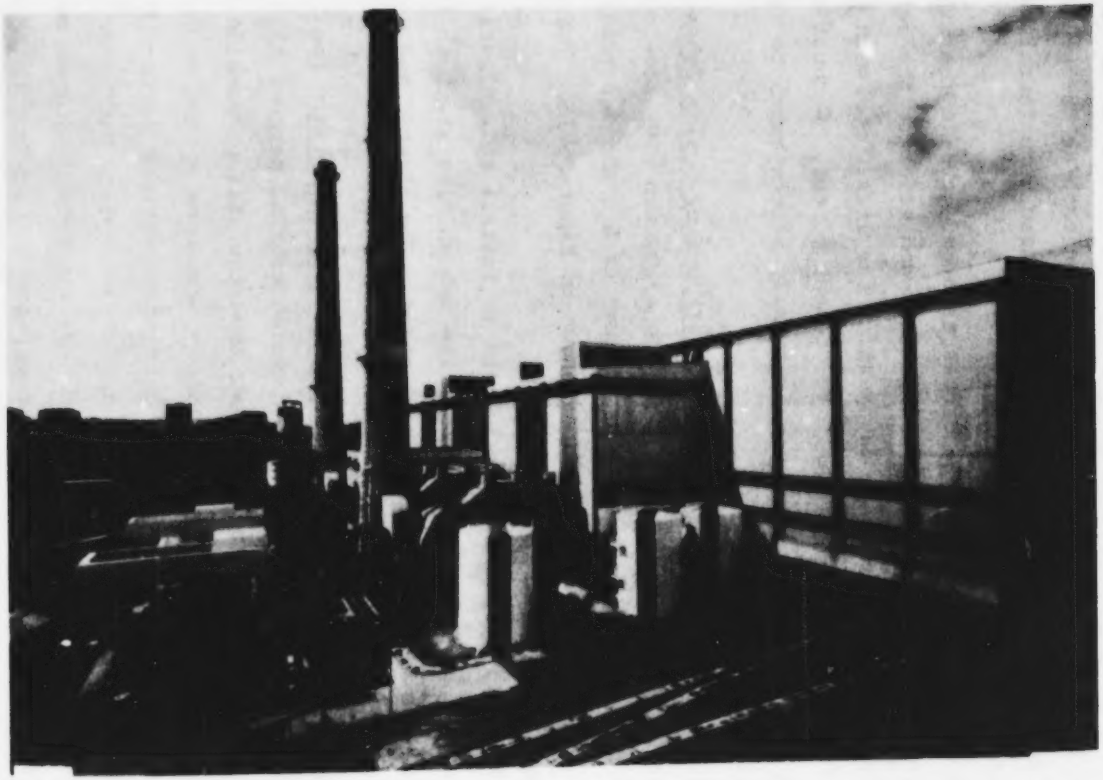


FIGURE 6-13. REAR VIEW SHOWING ASH CONVEYOR FROM THE RFSG PLANT TO THE ASH RECOVERY FACILITY AT PARIS: ISSY
(Courtesy of Josef Martin Feurungsbau, Gmbh)

Stage 2. Alumina Blocks Surrounding Boiler Tubes. The boiler tubes of the combustion chamber side walls were 70 mm(2.8 in) in diameter, the tube wall thickness was 4 mm(0.16 in) and the spacing was 160 to 180 mm (7 in). As a corrective measure, a shaped silicon carbide Carborundum block was designed and used as shown in Figure 6-14. These were installed from the stoker area up to the secondary air jets.

Cement was used to bond the blocks together. While the ash would not easily stick to the special blocks, it did stick to the cement mortar. Eventually in operation or in cleaning the slag, fused with the cement, would come off--pulling with it the cement mortar. Combustion air could then penetrate to the tubes. Eventually blocks began to fall. This system thus had to be replaced.

Stage 3. Plastic Silicon Carbide Surrounding Boiler Tubes. The third effort upon removal of the blocks was to apply ten (10) tons of plastic silicon carbide. A basically dry cement mixture of SiC and 8 percent H_2O was packed and rammed around the tubes as shown in Figure 6-15. The material was called Carbofrax SiC798B.

In 1966, two men worked for 2 weeks to install this plastic material. It should have lasted 5 years. The ash on slag stuck to the walls and would fall when the walls were cleaned. The plastic had nothing to stick to.

Stage 4. Studded Boiler Tubes Covered with Alumina. The fourth and current stage is use of welded studs covered with 42 percent Al_2O_3 plastic refractory. The alumina is cheaper than the silicon carbide and the binder bonds better at lower temperatures. The more expensive SiC has better wear once a proper bond is made. However, sometimes it is difficult to heat it for a long time-at-high temperature for a complete SiC bond. Wear has been much better with the Stage 4 approach. During scheduled downtime, maintenance people simply add more refractory around the studs in loosened, cracked, or fallen areas.

Furnace wall (First and Second Passes)

These two empty radiation passes have a heating surface area of 280 m^2 (3013 ft^2). The corresponding furnace volume is 290 m^3 (10,235 ft^3).

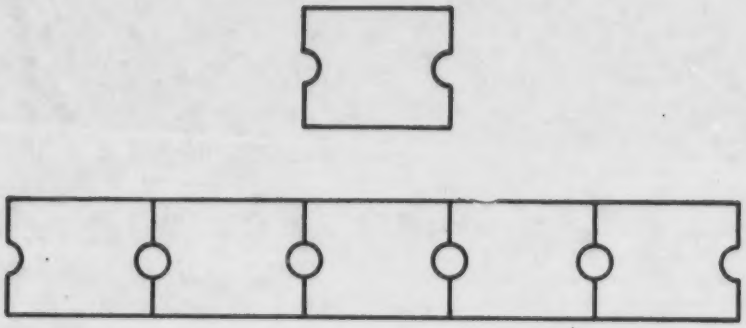


FIGURE 6-14. ISSY ALUMINA BLOCKS SURROUNDING BOILER TUBES

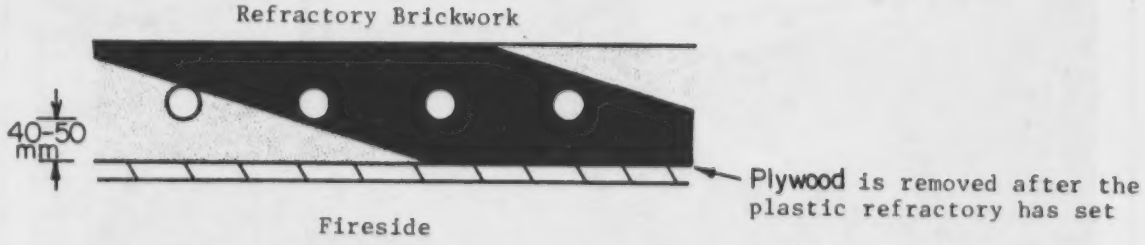
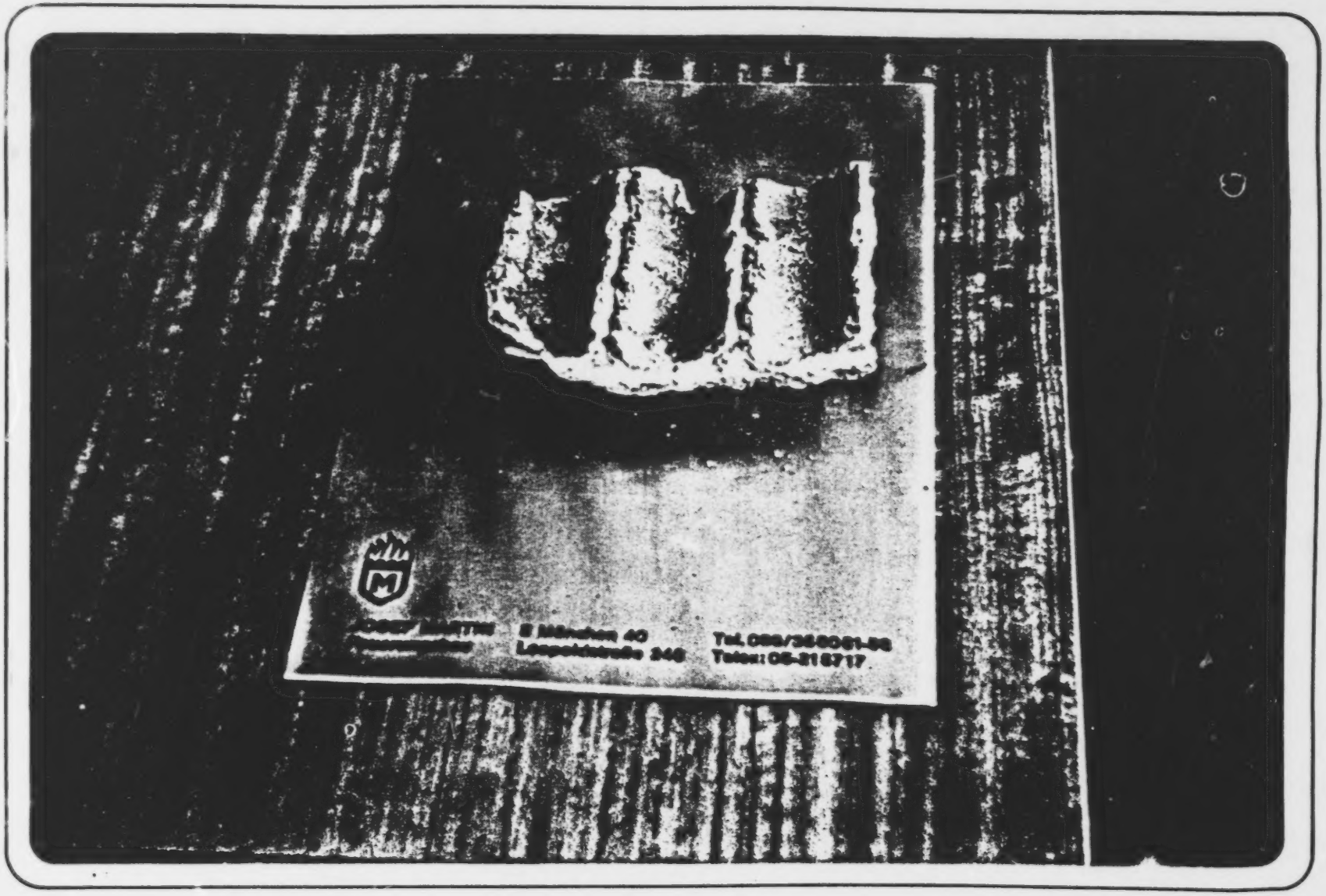


FIGURE 6-15. PLASTIC SILICON CARBIDE SURROUNDING BOILER TUBES



Reproduced from best available copy.

FIGURE 6-16. TYPICAL DEPOSITS CAREFULLY REMOVED FROM THREE WALL TUBES AT PARIS-ISSY

Stage 1. Original Bare Water Tube Walls. Originally the tubes were bare. The diameter was 70 mm (2.8 in) with a 4 mm (0.16 in) wall thickness. After 15,000 hours, many of the tubes had severe metal wastages or burst altogether. Thin or burst areas are shown in Figure 6-17a. Typical deposits carefully removed from the wall tubes are shown in Figure 6-16.

FIGURE 6-17a. ISSY METAL WASTAGE ZONES AND AREAS OF CORRECTIVE SHIELDING

Hypothetical reasons for metal wastage vary from (1) flame impingement, (2) alternating reducting-oxidizing atmospheres abrasive gases with high velocity.

Stage 2. Protective Shields Around Water Wall Tubes. Shields were then applied to these sensitive areas.

Stage 3. Metal Deflector Baffles in Second Pass. Because the superheater in the third pass was suffering erosive metal wastage, a metal deflector baffle was installed near the turning point at the bottom of the second pass as shown in Figure 6-17b.

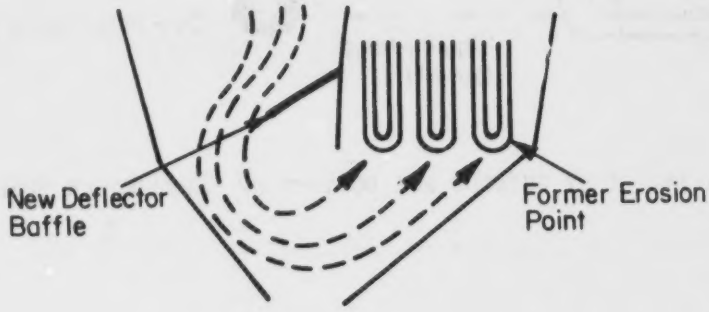


FIGURE 6-17b. ISSY NEW SECOND PASS DEFLECTOR BAFFLE TO PROTECT THIRD PASS SUPERHEATER

Stage 4. Plastic Silicon Carbide Surrounding Water Tube Wall. To further reduce metal wastage, Carborundum's Carbofrax SiC798B was applied in 1977.

Superheater (Third Pass)

Stage 1. (Original Design and Result). The superheater tubes are hung vertically in the third pass. The original superheater tubes were 38 mm (1.5 in) in diameter. The original design had 56 rows of tubes.

Conditions of combustion and running the units at 17 to 20 tonnes (19 to 22 tons) per hour instead of the rated 15 tonnes (16 tons) per hour overloaded the superheater tubes with deposits. With less cross-sectional space to travel through, the gas velocity was three times faster than design.

The coating of the superheater passage forced much gas to the outside and along the wall. Naturally the lower corner of the far superheater suffered from the very high velocity and volume of gas with particulate per unit time. The baffles, discussed in the second pass section were one of several solutions implemented after flow model studies were completed.

Stage 2. (Shields for Bottoms of Superheater Tubes). A new shield design was tried from 1967 to 1971. The two portions of Figure 6-18 depict the shield arrangement.

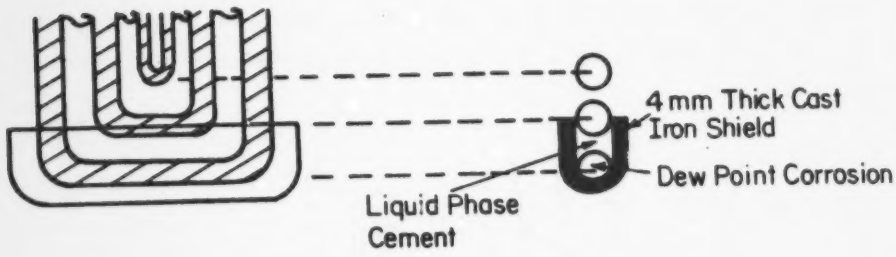


FIGURE 6-18. ISSY SHIELDS FOR BOTTOMS OF SUPERHEATER TUBES

The shields vertically cover the lower one and one-half tubes as shown. The cast iron shields were 4 mm(0.16 in)thick. The void was packed with a Narcoset (North American Refractories) liquid phase filler cement.

This new shielding was supposed to protect the superheater tubes for 4 to 5 years. However, superheater tubes began failing after 2 years or 11,000 hours. In an unusual manner the failure was attributed to the steam soot blower--not from erosion or regular corrosion but from condensation. The steam would condense and absorb into the Narcoset packing. Thus the occasionally wet packing would hygroscopically corrode the metal tube.

When the above effect was analyzed, the shields were discontinued. But erosive metal wastage continued.

Stage 3.(New Superheater with Wide Passes). The basic overloading apparently could not be relieved. Finally in 1973, a new superheater was installed. Normal slag deposits were later removed.

The 56 rows of superheater tubes were replaced by 31 rows. The tube diameter was increased from 38 mm (1.6in) to 44.5 mm (1.8 in). The old tubes were spaced as shown in Figure 6-19, as compared with the new spacing.

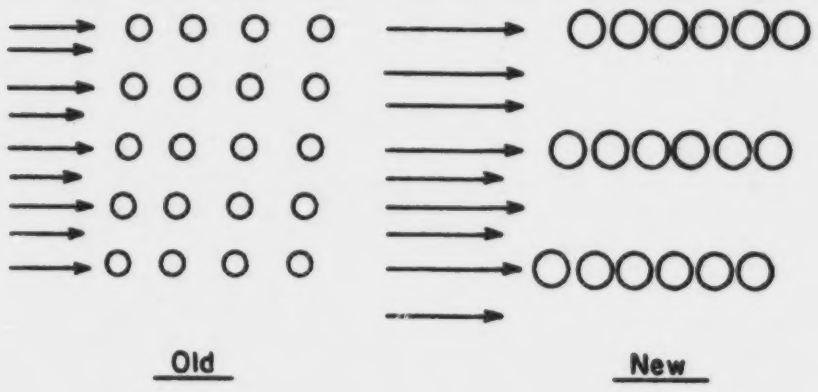


FIGURE 6-19. ISSY OLD AND NEW SUPERHEATER SPACING

Stage 4. Manual Cleaning of Superheaters. With the wider spacing between tubes, Issy has gone to manual cleaning of superheater

Boiler (Convection Section)

The convection section is 4m wide and 7.5m (24.6 feet) high. The section is 18 rows deep where each row has 40 tubes across; total surface = 1110 m^2 = 11950ft^2.

In this Issy unit, the sootblowers have not been as much of a problem as the high velocity directional changes. As discussed before, the furnaces are consuming a third more refuse as called for in the original design. With limited boiler dimensions, the additional gases must flow faster. Thus, on turning direction, the abrasive gases erode convection tubes more rapidly as was true of the superheater section. We do not mean to overemphasize this effect because tube failures are only beginning after 25,000 hours.

Economizer

Flue gases rise up through four bundles of economizer tubes that are in the six (6th) pass. Falling steel shot is the method for cleaning the boiler tubes. Because flue gas temperatures are low, little ash fusion occurs.

A sootblower might be too effective. The plant people were concerned about water slugs and a nozzle malfunction associated with sootblowing.

ENERGY UTILIZATION EQUIPMENT

Steam leaving the superheater enters first (1) the counterpressure (backpressure) and then (2) the condensing turbine. Each then, produce electricity. The energy still in the steam leaving the counterpressure turbine is partly used for district heating.

Referring to steam numbers as presented in "Table 6-5, Repeated" note that 964,718 tonnes (1,063,420 tons) of steam were produced in 1976. Steam condition was specified at 50 bars (725 psi) and 410 C (770 F). After the pressure relief valve and other losses 911,540 tonnes (1,004,800 tons) remained fo: constructive uses.

Electricity Generation

Similarly by referring back to "Table 6- 6 Repeated", results are shown for the two turbines.

Counterpressure (Backpressure) Turbine-Generator. The counterpressure turbine-generator set is rated at 9 mw. Figure 6-20 shows the control room.

The unit produced 43,597 mw in 1976 or 2/3 of Issy's output, an increase of 2.8 percent over 1975. Steam flowed through the unit for 8,382 hours but was available for 8,602 hours out of a possible 8,784 hours. The availability was thus 97.9 percent.

Because electricity was not always required, the generator's capacity wa used only 56.3 percent of the time. The unit produced 47.8 kw-hr of electricity per tonne of steam entering the turbine.

Condensing Turbine (Low Pressure). The other turbine, the low pressure condensing turbine-generator set, is rated at 16 mw. This unit while rated higher only produced 1/3 of Issy's output. This was 18.2 percent higher than in 1975. Steam flowed through the unit for 5,033 hours but was available for 8,602 hours out of a possible 8,782 hours. The availability was thus 97.9 percent as well.

Because of the high demand for district heating steam, this generator's capacity was used only 17.4 percent of the time. The unit produced 184.0 kw-hr of electricity per tonne of steam entering the turbine.

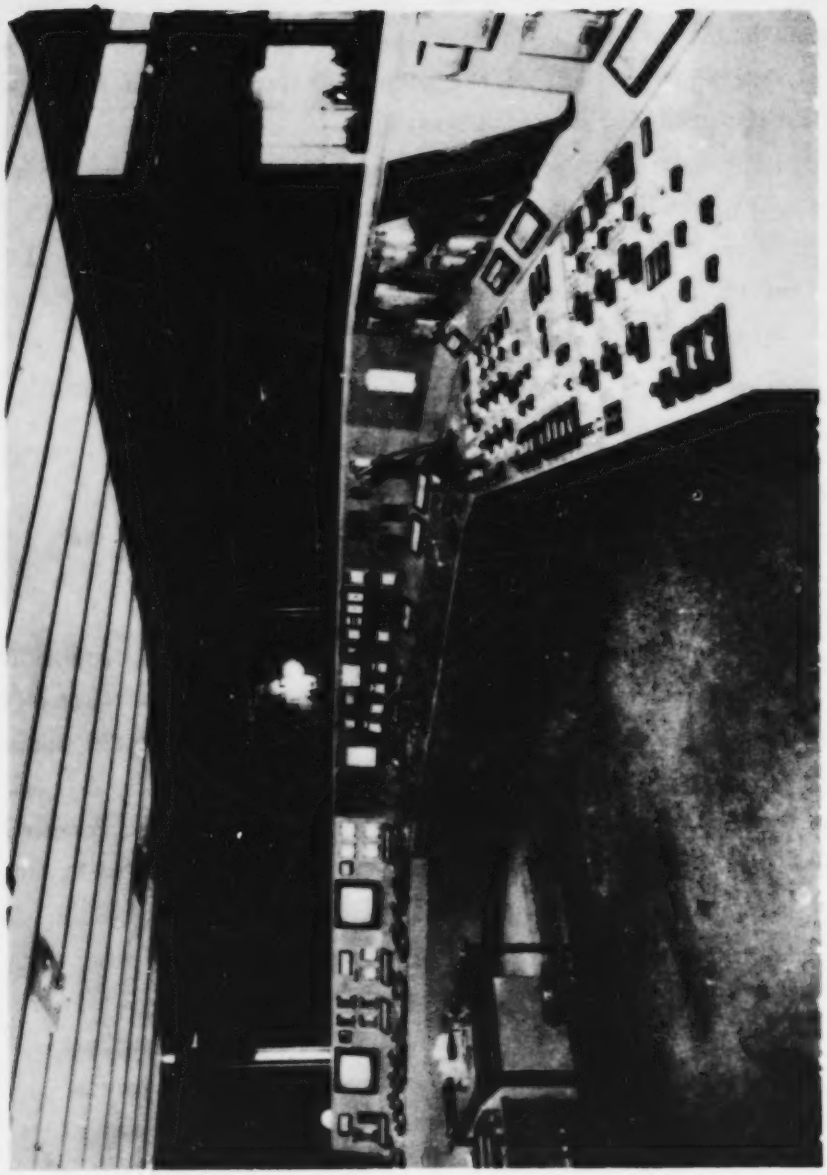


FIGURE 6-20. CONTROL ROOM AT PARIS-ISSY
(Courtesy of Josef Martin Feurungsbau, Gmbh)

TABLE 6-7. STEAM PRODUCTION, LOSSES, SALE AND AVAILABILITY
(For Convenience This Table Is Repeated From Page 16)

(Tonnes of Steam)	Month of December		Year of	
	1976	1975	1976	1975
Basic production of steam exiting boilers (50 bars, 410°C)	86,772	81,294	964,718	940,377
Loss at pressure relief valve	(1,026)	--	(14,598)	(3,503)
Technical sampling and losses	(3,256)	(4,077)	(38,580)	(43,172)
Available from boiler	82,490	77,217	911,540	893,702
Condensing turbines	(11,609)	(3,879)	(129,435)	(113,623)
Auxiliary condenser	(72)	--	(1,238)	(538)
Losses to atmosphere	--	(338)	(437)	(660)
Other losses	(614)	(2,380)	(6,241)	(35,082)
Sales to C.P.C.U.(1) for district heating	70,195	70,620	786,671	743,799
Average hourly vaporization during operation	33.2	29.5	33.2	31.9
Hours available of equipment to produce steam	2,880	2,875	30,567	30,348
Boiler availability	96.7	96.6	87.0	86.6
Percent utilization if boiler is available	75.3	70.7	78.9	77.5
Tonnes of steam per tonne of refuse	1.62	1.69	1.67	1.67

Source: TIRU Statistics.

(1) C.P.C.U. is the City of Paris Urban Heating Company.

TABLE 6-8. ELECTRICITY PRODUCTION, LOSSES SALE AND AVAILABILITY
(For Convenience This Table Is Repeated From Page 17)

(Mega watt-hours)	Month of December 1976	Month of December 1975	Year of 1976	Year of 1975
Production from counterpressure turbines	3,960	3,576	43,597	42,418
Production from condensing turbine	2,041	696	23,826	20,157
Total production	6,001	4,272	67,423	62,575
Purchase from C.I.M.E.	61	0	300	219
Total available	6,062	4,272	67,723	62,794
Internal uses of electricity	(1,752)	(1,608)	(19,654)	(18,753)
Electricity sale to C.I.M.E.	4,310	2,664	48,069	44,041
Internal consumption (Mw-h) of electricity per tonne of refuse burned	0.032	0.033	0.033	0.033
Counterpressue turbine actual hours	679	744	8,382	8,531
Condensing turbine actual hours	534	219	5,033	4,016
Counterpressure turbine hours available	744	744	8,602	8,613
Condensing turbine hours available	744	510	8,602	7,961
Counterpressure turbine availability	100	100	97.9	98.3
Condensing turbine availability	100	68.6	97.9	90.9
Counterpressure turbine utilization during availability	59.1	53.4	56.3	54.7
Condensing turbine utilization during availability	17.3	8.6	17.4	15.9
Production of electricity (Kw-h) per tonne of steam entering the:				
Counterpressure turbine	48.0	46.3	47.8	47.5
Condensing turbine	175.8	179.4	184.0	177.4

Source: TIRU Statistics.

Both Turbine-Generators. Table 6- 9 shows the five year history of electricity production, sales, purchases and internal consumption.

TABLE 6-9. HISTORY OF ELECTRICAL PRODUCTION, SALES, PURCHASES AND INTERNAL CONSUMPTION

	1972	1973	1974	1975	1976
Production	89,633	83,655	72,903	62,575	67,423
Purchases From C.I.M.E.	153	121	491	219	300
Internal Consumption	18,935	19,866	18,780	18,753	19,654
Sales to C.I.M.E.	70,851	63,910	54,614	44,041	48,069

Perhaps for street lighting, the Issy plant purchased 300 mw-hr from the other E.D.F. subsidiary for distribution: C.I.M.E. This gives a gross 67,423 mw-hr. Interestingly 29 percent of the electrical production (19,654 mw-hr) was used internally. This left 48,069 mw-hr for sale back to C.I.M.E. Internal consumption of electricity was 0.033 mw-hr per tonne of refuse burned.

C.P.C.U. District Heating Steam Inputs

To properly understand Issy, it is important to understand the total steam inputs to Issy's major steam (not electric) customer, C.P.C.U. C.P.C.U is the single distributor of district heating steam regardless of the fuel.

- C.P.C.U., also an E.D.F. subsidiary uses fossil fuel to produce steam
- An old T.I.R.U. power plant, closed in 1973, did supply a minor amount of steam to the network
- T.I.R.U., a subsidiary of E.D.F. produces steam from refuse.

Table 6-10 shows the maximum hourly capacity of the key organizational contributors.

Thus, all three T.I.R.U. refuse-fired plants only account for 29 to 33 percent of total C.P.C.U. demand. Issy, in 1975, produced only 12.3 percent of the total C.P.C.U. requirements.

TABLE 6-10. PRODUCTION FOR C.P.C.U. DISTRICT HEATING USES, PRODUCTION CAPACITY, CLIMATOLOGICAL CONDITIONS AND ANNUAL ACTUAL STEAM PRODUCTION

Hourly Installed Capacity (Tonnes/Hour)	1971	1972	1973	1974	1975
C.P.C.U. (Fossil Fuel)	1,690	1,840	1,870	2,470	2,510
E.D.F. (Steam from Old Power Plant)	300	300	300	--	--
T.I.R.U. (Refuse)	245	245	280	295	295
Production Capacity (Tonnes/Hour)	2,235	2,385	2,450	2,765	2,805

Climatological Conditions	1971	1972	1973	1974	1975
Average 7-Month Heating Season					
Temperature °C	7.38	7.82	6.92	8.42	7.39
Degree Days	2252	2168	2349	2031	2250

Annual Actual Production Used by C.P.C.U. for District Heating (Thousand Tonnes/Year)	1971	1972	1973	1974	1975	1976
C.P.C.U. (Fossil Fuel)	2,963	3,957	4,095	3,697	4,029	
E.D.F. (Closed)	306	97	240	224	--	--
Issy (Refuse)	↑	603	653	644	744	787
Ivry (Refuse)	1,670	639	767	784	852	767
Saint-Ouen (Refuse)	↓	411	392	403	415	404
Inconsistencies	0	3	2	(3)	0	
Actual Steam Production	4,939	5,710	6,149	5,747	6,040	

C.P.C.U's growth in demand was about 10 percent per year until the oil crisis. Their own oil fired plants then became less competitive. Customers in new buildings returned to consideration of small electric or gas fired heating systems.

The steam is distributed in insulated pipes as shown in Figure 6-21. The return condensate pipe is in the same tunnel.

The monthly pattern shown in Figure 6-22 clearly shows that all three of the TIRU refuse fired plants provide the base load. Only during the important August vacation, does the TIRU production fall to 90,000 tonnes (99,000 tons) per month compared to 210,000 tonnes (231,000 tons) in January. The fossil fueled C.P.C.U. steam production plants are clearly peak loading plants.

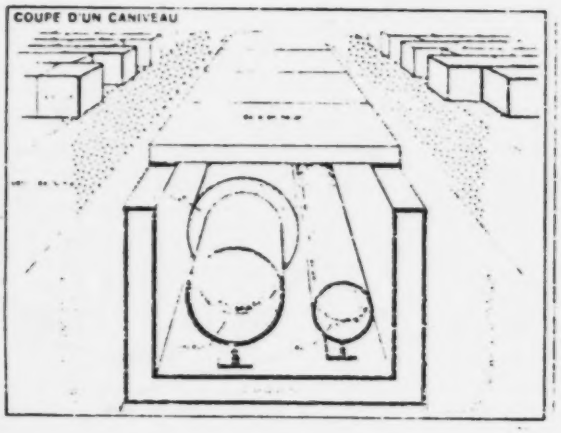


FIGURE 6-21. STEAM DISTRIBUTION AND RETURN CONDENSATE PIPES OF C.P.C.U. IN PARIS

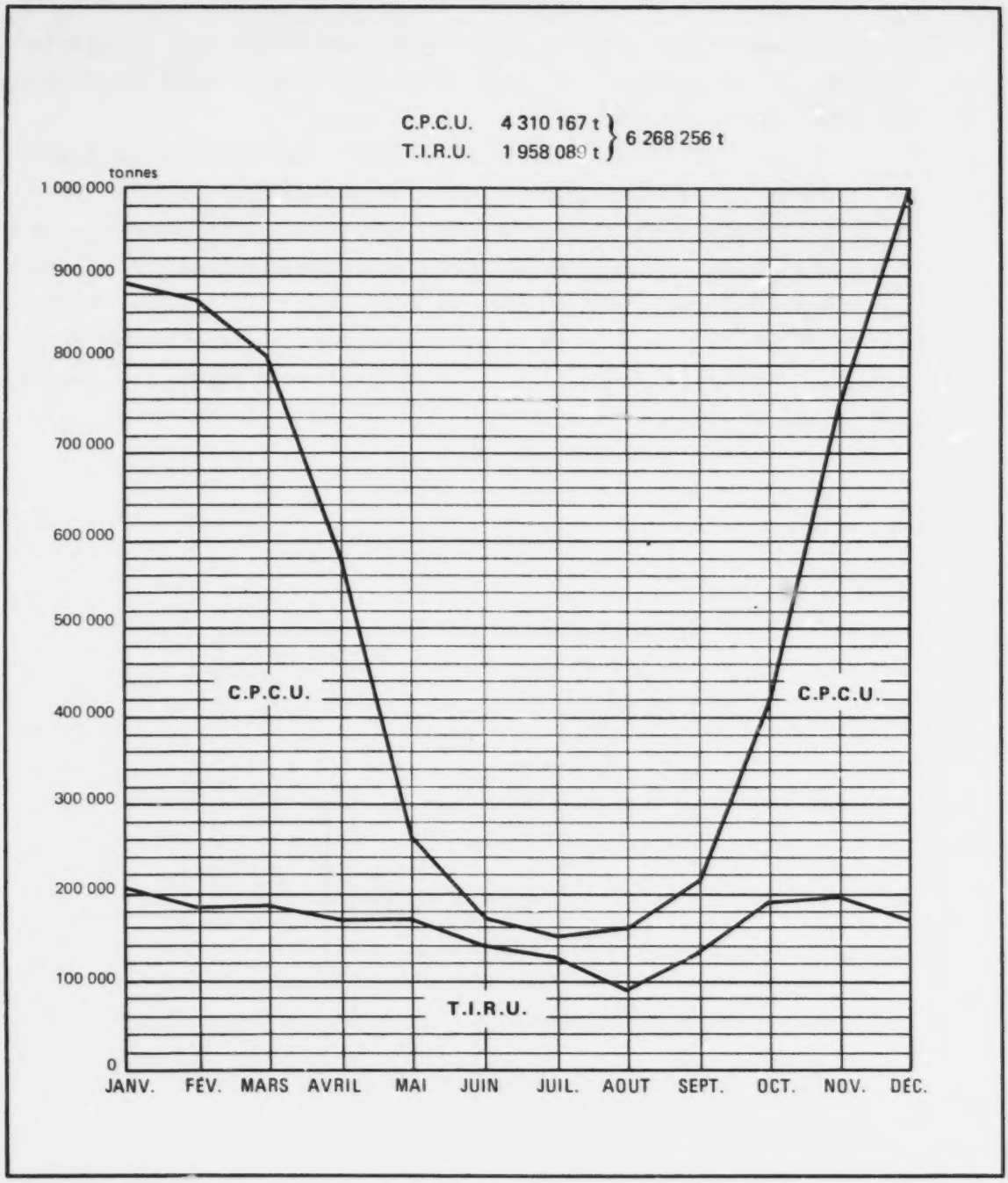


FIGURE 6-22. STEAM PRODUCED BY TIRU (SOLIDWASTE FUELED) AND BY C.P.C.U. (FOSSIL FUELED) IN PARIS

The 5-year history describing the C.P.C.U. district heating network is portrayed in Table 6-11. In December 31, 1975, the trunk line was 196 km (122 miles) long while the branch lines were only 29 km (18 miles) long for a grand total of 225 km (140 miles).

The heat density has been gradually rising up to 13.1 kilo therms per hour per kilometer of pipe. The return condensate percent averages about 91 percent.

By 1975, 3,208 buildings were receiving steam 2,561 kth/hour were being delivered.

Slightly over a third of the energy goes to residences and a third to offices as seen in Table 6-12.

TABLE 6-11. C.P.C.U DISTRICT HEATING NETWORK FACTS

	1971	1972	1973	1974	1975	1976
Trunk Pipe Line Distance (Km)	167	174	181	193	196	
Branch Pipe Line Distance (Km)	22	23	25	27	29	
TOTAL Network Pipeline Distance (Km)	189	197	206	220	225	
Pipeline Heat Density (Kth/hr/Km)	10.7	11.3	11.9	12.4	13.1	
Return Condensate (Percent)	91.4	90.2	91.1	90.5	91.2	
Number of Buildings	2,526	2,703	2,878	3,029	3,208	
Energy Delivered (Kth/hr)	1,794	1,970	2,162	2,400	2,561	

TABLE 6-12. C.P.C.U. PERCENT DISTRIBUTION OF CUSTOMERS

	1971	1972	1973	1974	1975	1976
Residences	28.3	30.8	32.5	33.5	34.6	
Hotels, Cafes, Restaurants	3.4	3.4	3.1	3.5	3.4	
Offices	36.9	36.8	37.1	36.3	35.5	
Hospitals, Clinics, Nurseries	7.7	7.1	6.9	7.8	7.4	
Schools, Universities, Churches	14.8	13.8	12.9	11.7	11.8	
Miscellaneous	8.9	8.1	7.5	7.2	7.3	
	100.0	100.0	100.0	100.0	100.0	

POLLUTION CONTROL EQUIPMENT

The four furnaces, with four Lurgi electrostatic precipitators (ESP) feed into two chimneys, (See Figure 6-1)

Furnace Exit Conditions

Each boiler supplies 130,000-150,000 Nm^3/hr of 300 C (572 F) temperature combustion gases.

A typical boiler exit gas composition adjusted to 7 percent CO_2 is as follows:

- Particulates 2000 to 5000 mg/Nm^3
- CO_2 7 percent
- O_2 11 percent
- N_2 69 percent
- H_2O 13 percent
- SO_2 100 to 400 mg/Nm^3
- NO_x 100 to 200 mg/Nm^3
- HCℓ 1100 to 1600 mg/Nm^3
- HF traces

The particle size distribution less than 10 μM is 7.5 percent to 10.0 percent.

Precipitator Characteristics

Disregarding the hopper, each precipitator is 15.5 m (51 feet) high 9.2 m (30 feet) wide and 10.2 m (33 feet) deep. A dividing guilotine damper wall is inside each precipitator. This permits half a precipitator to operate if the other half is damaged.

The design was not preceeded by a flow-model study.

The average flow velocity in the ESP is 0.925 m (3 feet) per second. Two perforated plates at the ESP entrance uniformly distribute the gas. The units have two (2) fields in series. Each unit has a collection plate surface of 4320 cm. The plates are approximately 40 cm (16 in.) wide and curved at each edge. These collector plates are spaced 20 cm (8 in.) from the wires. Falling hammers clean the plates.

The output voltage is 76,000 volts and the output current is 0.42 amperes. The capacity is 30 Kva.

The pyramidal fly ash hoppers have no method for heating. Fly ash is removed pneumatically. Ivry also has pneumatic removal but later Martin installations have used screws to remove flyash. Efficiency was guaranteed at 98 percent.

A notable philosophy of TIRU management is that full air pollution stack tests are conducted once per month. Three men do the sampling after the induced draft fan (just ahead of the stack) while the gas is in a horizontal flow. Issy uses fewer points than the standard 48 points used at Ivry. The testing aparatus is portrayed in Figure 6-23.

Gas passes through cyclones and quartz filters for 10 minutes at each point. Tests on the four Issy furnaces in late February, 1977, showed particulates at 36 to 59 mg/Nm^3 adjusted to 7 percent CO_2-- certainly within the 80 mg/Nm^3 limit on particulates.

During the emission tests, the crew also measures the energy lost in the residue's unburnt carbon as well as other losses. Refuse weight measurements from the crane's load cell are carefully taken and recorded during the tests. This information permits the monthly calculation of the LHV of refuse.

Performance of the ESP's was only a problem during shakedown and initial startup operations. The frequent starts and stops likely caused moisture to condense and corrosion to occur; but mainly at the ESP's front end. Wire breakage was the resultant effect. Now routine maintenance inspection during scheduled shutdowns and minor parts replacement are all that is needed. In recent years of normal operation, the ESPs are almost 100 percent reliable.

In the past and at some unknown French furnace (codes were used), detailed air pollution tests were made. Results are presented in Table 6-12 and Table 6-13 because some very unique pollutants were tested.

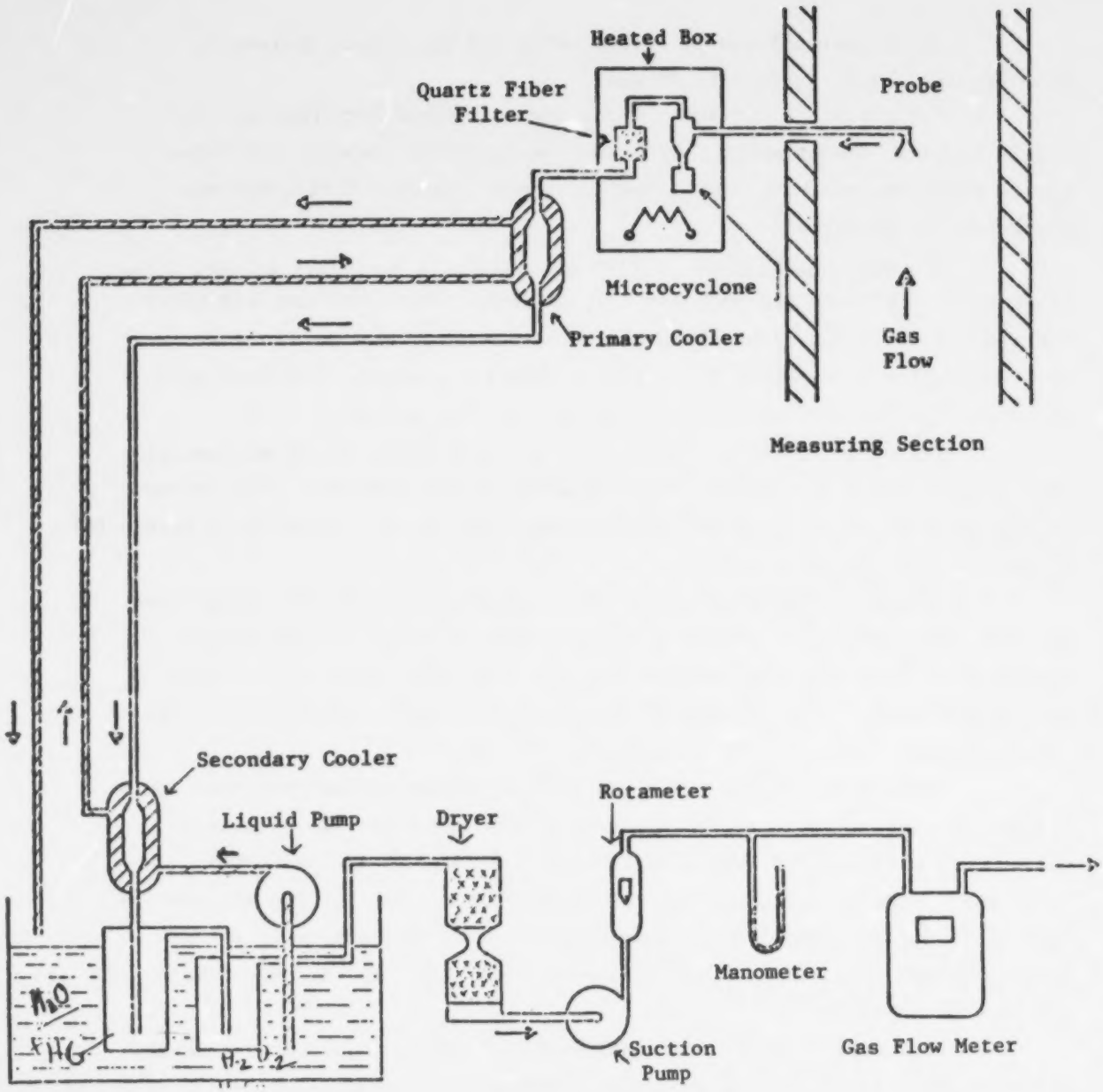


FIGURE 6-23. APPARATUS FOR MEASUREMENT OF DUST LOADING AND MOISTURE IN A GAS STEAM (Courtesy Traitment Industrial des Residus Urbans)

TABLE 13. AIR POLLUTION TEST RESULTS ON AN UNSPECIFIED FRENCH PLANT

	Units	Furnace No. 1	Furnace No. 2	Furnace No.3	Furnace No. 4
Date (1977)		2/28	2/25	2/23	2/22
Rate of Incineration	(refuse tonnes/ hour)	20.11	19.16	15.73	18.43
Rate of Steam Production	(steam tonnes/ hour)	30.82	32.46	28.97	31.11
Temperature at Furnace Roof	(° C)	880	928	956	896
Temperature at Boiler Exit	(°C)	334	308	388	283
Volume leaving ESP	(Nm^3/hour)	100,190	95,250	97,910	108,910
Humidity Leaving ESP	(%)	12.2	13.1	16.8	11.9
Emission Leaving ESP	(%)				
CO_2		6.1	6.5	7.1	6.2
O_2		11.0	10.8	9.4	11.1
Particulates (@ 7% CO_2)	(Mg/Nm^3)	42	36	59	47
SO_2 and SO_3 (@ 7% CO_2)	(Mg/Nm^3)	126	130	132	139
NO and NO_2 (@ 7% CO_2)	(Mg/Nm^3)	97	141	138	163
HCl (@ 7% CO_2)	(Mg/Nm^3)	1,335	1,509	1,744	1,074

Source: TIRU Division Controle Technique
Section Laboratoire et Essais

TABLE 6-14. FRENCH REFUSE FIRED STEAM GENERATOR AIR POLLUTION TEST RESULTS

Item	Measurement and Unit
GENERAL	
Code Letter	H
Furnace Capacity	17 tonnes per hour
Average Throughput	16 tonnes per hour
Heat Recovery	Yes
Air Pollution Control	Electrostatic precipitator
Chimney Elevation	80 meters
FURNACE	
Gas Composition Exiting From Boiler	
CO_2	8.8%
O_2	11.5%
Water Vapor	130 g/Nm^3
Excess Air	120 %
Gas Temperature	
Exit of Hearth	850 C
Exit of First Pass	755 C
Entrance to ESP	295 C
Exit from ESP	275 C
Volume Discharge of Gas to Chimney	67,000 Nm^3/hour
Period of Sampling	26 hours
ESP Efficiency	96 %
Amount of Particulates Entering the ESP	1,585 Mg/Nm^3

TABLE 6-14.(Continued)

Item	Measurement and Unit
POLLUTANTS EMITTED TO THE CHIMNEY (Adjusted to 7 % CO_2)	
Particulates	
Particulates leaving ESP	50 mg/Nm^3
Fraction Soluble in Water	7 %
Fraction Soluble in Organic Solvents	0.1 %
Inorganic Gases	
HCℓ	430 mg/Nm^3
SO_2	80 mg/Nm^3
H_2SO_4	2 mg/Nm^3
NO	40 mg/Nm^3
Organic Gases	
Acids (an acid form HCOOH)	
Aldehydes	
Ketones	
Alcohols	2.6 mg/Nm^3
Phenols and polyphenols	
Aliphatic compounds	
Cyclic and polycyclic compounds	
Diverse organic compounds of N,S and Cℓ	0.2 mg/Nm^3
Acid condensate	117 milliequiv grams $H+/dm^3$
pH	1

Induced Draft Fan

The I.D. fans are also manufactured by Pratt and are located at ground level just before the chimney.

To increase the longevity of the fan, "Crinite" material was specifically welded to the fan blades as depicted in Figure 6-24. The wear is then on the welded beads instead of the fan blades. As the beads then can be rewelded during routine maintenance.

FIGURE 6-24. CRINITE WELDED BEADS ON FAN BLADES AT PARIS: ISSY

Stack Construction

The two chimneys are built of reinforced concrete.

PERSONNEL AND MANAGEMENT

Electricitie' de France (E.D.F.) is France's national electric company and is owned by the Federal government. In 1946, E.D.F. established the Service du Traitment Industriel des Rèsidus Urbans (T.I.R.U.) for the purpose of operating refuse-fired steam generators.

Products from the T.I.R.U. plants were to be:

- Electricity sold to T.I.R.U.'s sister company, C.I.M.E. which is E.D.F.'s electricity distribution subsidiary.
- Steam sold to a separate organization, Compagnie Parisimne de Chauffage Urbain (C.P.C.U.).

It is important to understand how all of these large organizations relate. With that understanding, the personnel and management situation of T.I.R.U. and it's Issy plant can be placed on its proper perspective. As indicated earlier in the report, the City of Paris has a parallel contractual relation as do 54 other metropolitan communities.

The T.I.R.U. organization chart is shown in Figure 6-25. Mr. Defeche is the Chief of the Service T.I.R.U. The plant managers report to him as does Mr. Jullien, Director of the Technical Department. The other positions are shown including Mr. Finet, head of the Pollution Control Section.

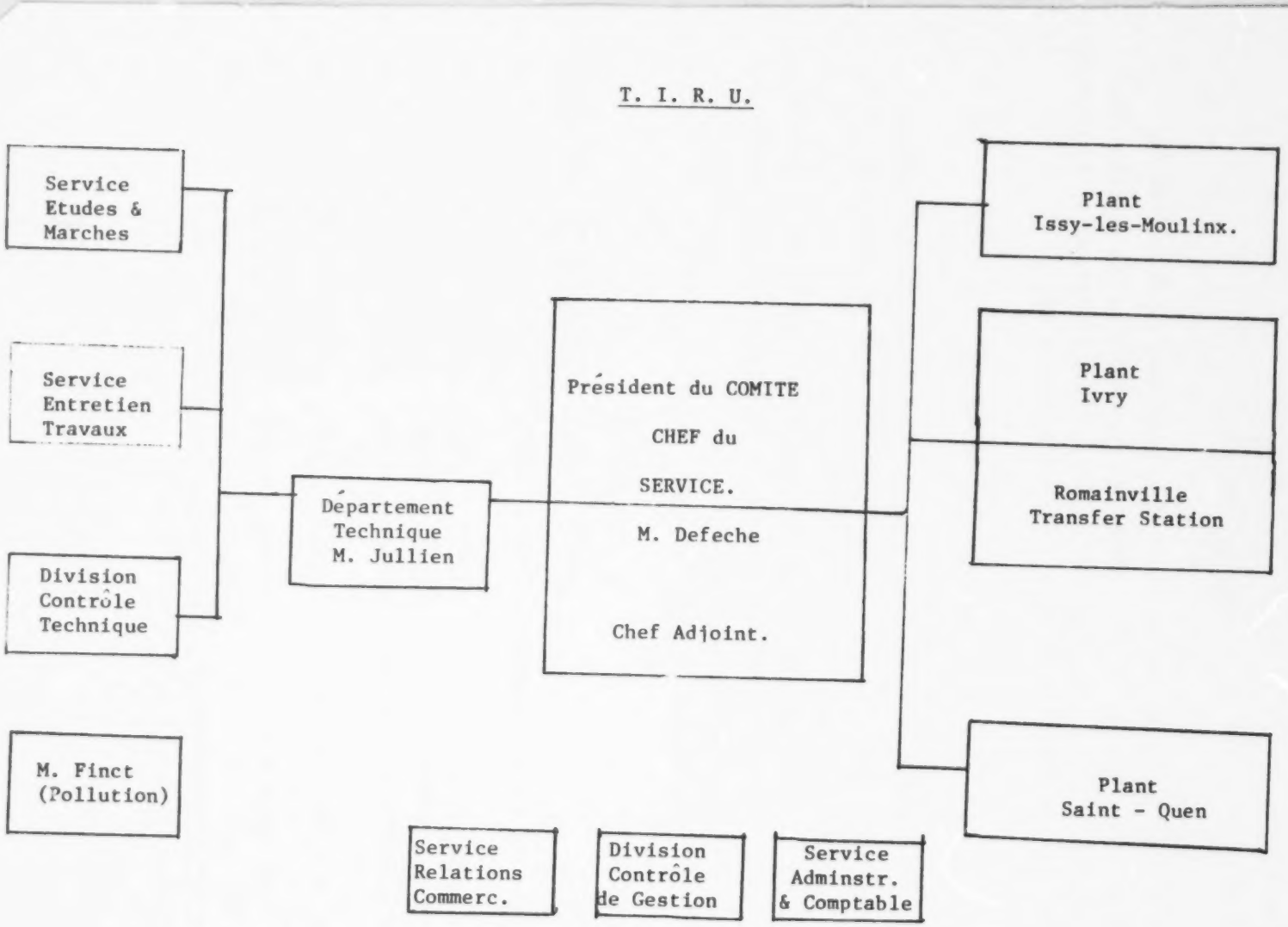


FIGURE 6-25. ORGANIZATION CHART OF TIRU IN PARIS

ECONOMICS

Capital Investment

The Paris:Issy-les-Moulineaux plant was built in 1962 for 110,000,000 Fr ($22,700,000). The plant was built on the previous Issy incinerator site so the land cost nothing. Roughly 600,000 Fr fr ($120,000) was spent to tear the old plant down and level the area.

Annual Financial Figures

Tables 6-15 and 6-16 display the 1976 expense and revenue figures for Issy. The tables respectively present the total numbers in Fr fr and Fr fr/tonne.

The tables are unusual in that traditional "labor", "materials", etc. accounts are separated according to activities such as "testing and verification", "training and safety", etc.

Key figures of this table are summarized below:

	Total Basis (000's)		Per Tonne Basis		Per Ton Basis
	Fr fr	$*	Fr fr/T	$/T*	$/Ton
Operating and Maintenance Expenses	27,060	5,574	45.99	9.47	8.52
Other Expenses	14,065	2,897	23.90	4.92	4.43
TOTAL EXPENSES	41,125	8,471	69.89	14.39	12.95
Sales of Electricity and Steam	20,091	4,139	34.14	7.03	6.33
Sales of Road Ash and Metal	828	170	1.41	.29	.26
TOTAL REVENUE	20,919	4,309	35.55	7.32	6.59
NET COST	20,206	4,162	34.34	7.07	6.36

* Converted at $0.206 equals 1 French franc.
** Converted at .9 Tonne equals 1 ton.

TABLE 6-15. FINANCIAL RESULTS OF TIRU 1976 OPERATIONS AT THE PARIS: ISSY PLANT (THOUSANDS OF FRENCH FRANCS)

	Labor	Supervision and Management	Enterprises	Equipment Purchases	Storeroom Purchases	Other Expenses (Revenues)	Total Expenses
Operations Expenses	6,413	443	1,053	504	23	5	8,441
Maintenance - General	4,089	78	1,083	419	790	556	7,015
Maintenance Inspections	367	11	2,844	82	1,127	77	4,508
Maintenance - Specific	9		655	643	120		1,427
Testing and Verification	1,237	2	25	44	48	406	1,762
Revisions After Testing	71				18	1	90
	16		391	42	3		452
			64	15		449	528
Training and Safety	242		107	30	24	(92)	311
Purchased Services	981	86	1	5	1	183	1,257
General Expenses	197	23	679	149	3	218	1,269
Total Operating and Maintenance Expenses	13,622	643	6,902	1,933	2,157	1,818	27,060
Transporting Waste			485			436	921
Sales Expense	19					6	25
Amortization						7,813	7,813
Interest Charges						491	491
Share of Central Services	2,685	57	95	95		1,883	4,815
Total Other Expenses	2,704	57	580	95		10,629	14,065
TOTAL EXPENSES	16,326	700	7,482	2,028	2,157	12,432	41,125
Sales of Electricity and Steam						(20,091)	(20,091)
Sales of Road Ash and Scrap Metal						(828)	(828)
TOTAL REVENUE						(20,919)	(20,919)
NET RESULT	16,326	700	7,482	2,028	2,157	(8,487)	20,200

TABLE 6-16. FINANCIAL RESULTS OF TIRU 1976 OPERATIONS AT PARIS: ISSY PLANT (FRENCH FRANCS PER REFUSE INPUT TONNE)

	Labor	Supervision and Management	Enterprises	Equipment Purchases	Storeroom Purchases	Other Expenses (Revenues)	Total Expenses
Operations Expenses	10.90	0.75	1.79	0.85	0.04	0.01	14.34
Maintenance - General	6.95	0.13	1.84	0.71	1.35	0.94	11.92
Maintenance Inspections	0.62	0.02	4.83	0.14	1.92	0.13	7.66
Maintenance - Specific	0.02		1.11	1.09	0.20		2.42
Testing and Verification	2.11		0.04	0.08	0.08	0.69	3.00
Revisions After Testing	0.12				0.03		0.15
	0.03		0.67	0.07			0.73
			0.11	0.03		0.76	0.90
Training and Safety	0.41		0.18	0.05	0.04	0.15	0.53
Purchased Services	1.67	0.15		0.01		0.31	2.14
General Expenses	0.33	0.04	1.16	0.26		0.37	2.16
Total Operating and Maintenance Expenses	23.16	1.09	11.73	3.29	3.66	3.06	45.99
Transporting Waste			0.83			0.74	1.57
Sales Expense	0.03					0.01	0.04
Amortization						13.28	13.28
Interest Charges						0.83	0.83
Share of Central Services	4.56	0.10	0.16	0.16		3.20	8.18
Total Other Expenses	4.59	0.10	0.99	0.16		18.06	23.90
TOTAL EXPENSES	27.75	1.19	12.72	3.45		21.12	69.89
Sales of Electricity and Steam						(34.14)	(34.14)
Sales of Road Ash and Scrap Metal						(1.41)	(1.41)
TOTAL REVENUE						(35.55)	(35.55)
NET RESULT	27.75	1.19	12.72	3.45	3.66	(14.43)	34.34

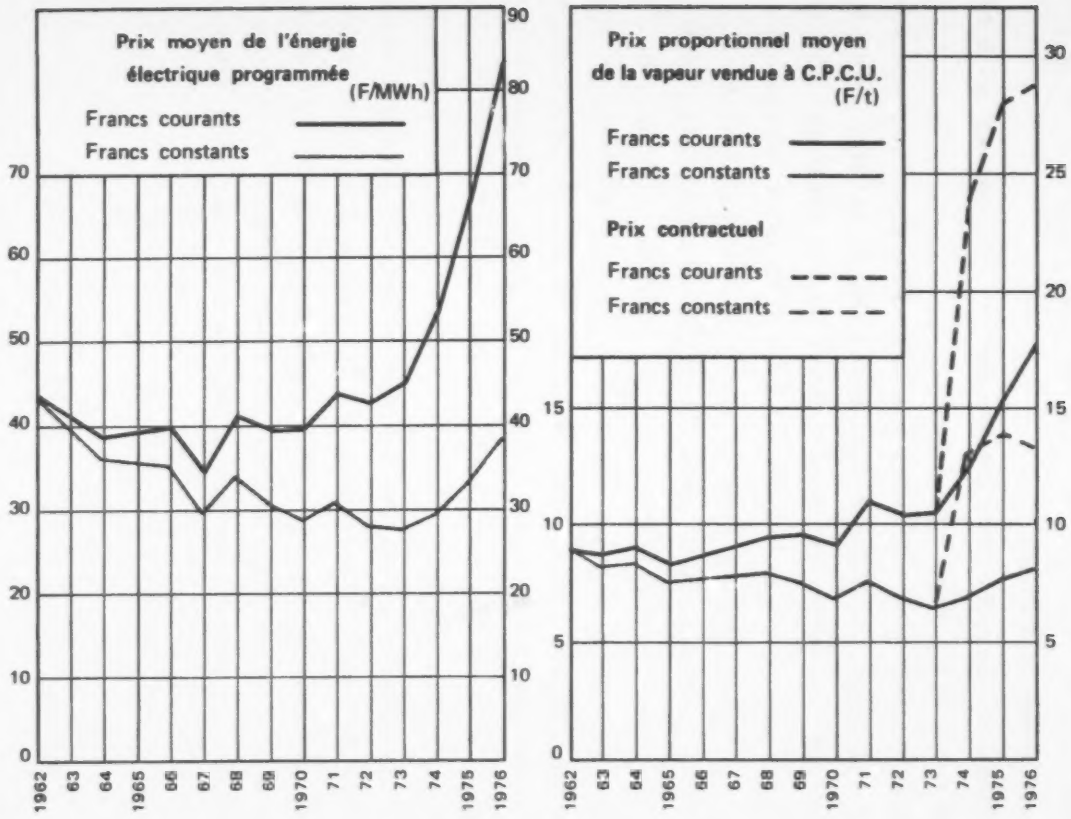
A per ton expense figure of $12.95 is an accomplishment for which the staff of TIRU can be most proud. Selling electricity and steam for district heating at $6.59/refuse ton have enabled TIRU to recover about half of their costs. The net cost figure of $6.36 is one of the best figures in Europe.

Financial details covering the period 1962 through 1976 are pictured in the several remaining figures.

Figures 6-26 and 6-27 show the unit sale price pattern for electricity and steam. The upper line shows the inflated current francs, while the bottom line shows the same results but in constant 1962 francs. The jump in the last 3 years was caused by a TIRU labor settlement being at a higher increase than the general level of French inflation.

Total expenses and revenue components are shown in the following figures. Figure 6-28 shows current francs while and also in 1962 constant francs. These figures parallel a Battelle observation about RFSG revenues in both Europe and in North America. Generally speaking, a system that has a heavy load of district heating (and possibly summer cooling) will have greater revenue than a system making only electricity.

Practically speaking, however, it may be more difficult to institutionally develop a district heating market and pure electrical production may be the only alternative. The reason for lower revenues from electricity sale is that the RFSG plant must compete with conventional fossil fueled or nuclear power plants 100 times bigger. In most countries, there is a national grid of economically produced power that forces a low sale price for electricity.



FIGURES 6-26. AND 6-27. UNIT PRICES FOR ELECTRICITY AND STEAM IN PARIS (TIRU)

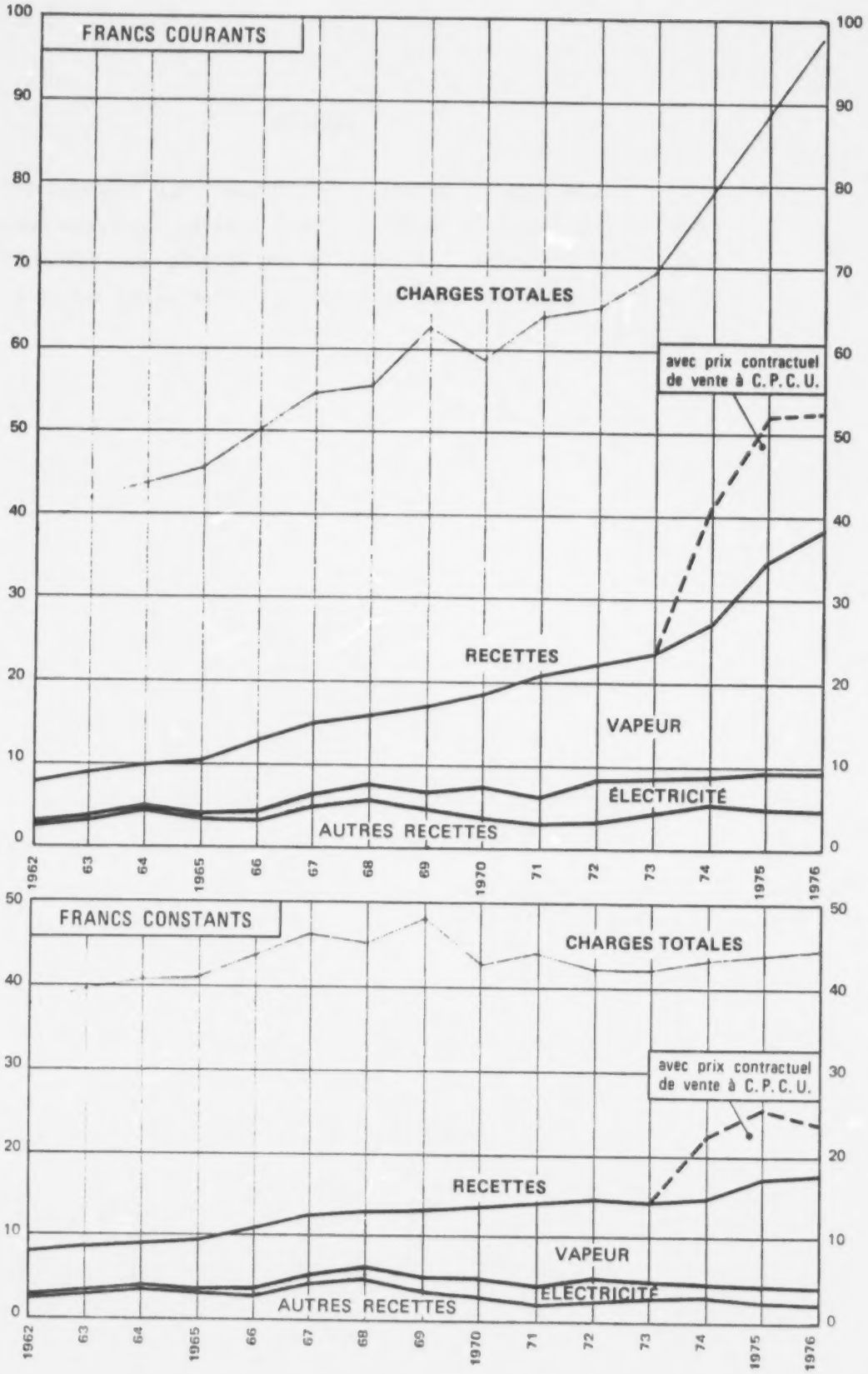


FIGURE 6-28: REVENUE AND EXPENSE COMPONENTS FOR THE FOUR TIRU PLANTS

FINANCE

The 110,000,000 Frfr ($22,700,000) was financed by the City of Paris's larger general obligation bond sold to insurance companies and other large investors. Payments on the 20-year bond began in 1964 at a 6.5 percent interest rate. The rate has fluctuated and is currently 8 percent.

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(2) Defèche, J. et al, EDF TIRU, 1976, Servicie du Traitement Industriel des Rèsidus Urbains, Rapport D'Activitá (The TIRU 1976 Annual Report).

(3) Compagnie Parisienne de Chauffage Urban (CPCU) (Small brochure showing 1976 operating results for the Paris Company for Urban District Heating.

(4) Circulaire du 6 June 1972, Relative airx Usines D' Incineration de Residus Urbains (The newly proclaimed environmental regulations for incinerators).

(5) Quelques resultats cumules pour la France entiere (Some cumulative statistiçal results for all of France regarding solid waste disposal alternatives used) T.S.M. - L'EAU November 1975-Supplement.

(6) Devis Programme Type Pour la Miso au Concours des Installations D'Incineration de Résidus Urbains - Cahier des Prescriptions Spéciales (Work program standard, Vendors' proposals for construction are to be responsive to these specific items.) 31 pages

(7) "Interet economique de la recuperation d' energie par incineration d'ordures menagères" Report of the working group "Incineration des ordures menageres avec recuperation d'energie" of the agency for energy economics (Economic interest in the recovery of energy from incineration of household waste--an intense econometric analysis). Techniques et Science Municipales No.10-76 Supplement

(8) Inventaire des installations de traitement des ordures menageres. (Inventory of Installations for Treatment of Household Wastes). Plan from the Ministére of the Quality of the Life Techniques et Sciences Municipales No. 11-75 Supplement.

DEFINITIONS AND ABREVIATIONS

C.P.C.	Cahier des Prescriptions Communes (The book of Community regulations)
C.P.S	Cahier des Prescriptions Speciales (The book of special regulations -- referring to mineration).
T.I.R.U.	Service du Traitement Industrial des Residus Urbains (Service for the industrial treatment of urban waste)
E.D.F.	Electricitve de France (The French government owned electric public utility).
C.P.C.U	Compagnie Parisienne de Chauffage Urbain (The Paris Company for Urban district heating).

CONVERSION FACTORS

English Units Versus SI (and Metric) Units

To Convert From	To Get	Multiply by	To Convert From	To Get	Multiply by
feet	meters	0.3048	meters	feet	3.281
square feet	square meters	0.0929	square meters	square feet	10.76
cubic feet	cubic meters	0.0283	cubic meters	cubic feet	35.31
inches	millimeters	25.4	millimeters	inches	0.0394
cubic yards	cubic meters	0.7646	cubic meters	cubic yards	1.308
barrels (oil)	cubic meters	0.15899	cubic meters	barrels (oil)	6.290
miles	kilometers	1.609	kilometers	miles	0.6214
square miles	square kilometers	2.589	square kilometers	square miles	0.3861
acres	square kilometers	0.004047	square kilometers	acres	247.1
acres	hectares	0.4047	hectares	acres	2.471
gallons	cubic meters	0.003785	cubic meters	gallons	264.2
ton (short)	tonne (metric)	0.9078	tonne (metric)	ton (short)	1.102
pounds	grams	454	grams	pounds	0.002046
grains	grams	0.0648	grams	grains	15.42

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CONVERSION FACTORS

English Units Versus SI (and Metric) Units

To Convert From	To Get	Multiply by	To Convert From	To Get	Multiply by
pounds per million Btu	nanograms per Joule	499.2	nanograms per Joule	pounds per million Btu	0.0023
pounds per million Btu	milligrams per megajoule	499.2	milligrams per megajoule	pounds per million Btu	0.00233
cubic feet per minute	cubic meters per hour	1.699	cubic meters per hour	cubic feet per minute	0.588
gallons per minute	liters per minute	3.785	liters per minute	gallons per minute	0.264
pounds per square foot	kilograms per square meter	703.1	kilograms per square meter	pounds per square foot	0.001422
pounds per square inch	kilograms per square centimeter	0.07031	kilograms per square centimeter	pounds per square inch	14.223
pounds per square inch	atmospheres	0.0681	atmospheres	pounds per square inch	14.69
pounds per square inch	newtons per square meter	6894.8	newtons per square meter	pounds per square inch	0.00014
pounds per square inch	kilopascals	6.8948	kilopascals	pounds per square inch	0.1450
atmospheres	bars	1.0133	bars	atmospheres	0.9869
atmospheres	kilopascals	101.3	kilopascals	atmospheres	0.0098
pounds per square inch	bars	0.06895	bars	pounds per square inch	14.50
inches of water	pascals	249.08	pascals	inches of water	0.004015
millimeters of water	pascals	9.806	pascals	millimeters of water	0.102

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CONVERSION FACTORS

English Units Versus SI (and Metric) Units

To Convert From	To Get	Multiply by	To Convert From	To Get	Multiply by
Btu	kilocalorie	0.252	kilocalorie	Btu	3.968
MBtu	Gcal	0.252	Gcal	MBtu	3.968
Btu	kilowatt-hours	0.000293	kilowatt-hours	Btu	3414
Btu	Joules	1055.1	Joules	Btu	0.000948
Btu per pound	kilocalories per kilogram	0.5555	kilocalories per kilogram	Btu per pound	1.8
Btu per pound	Joules per kilogram	2326	Joules per kilogram	Btu per pound	0.00430
Btu per hour	watts	0.29307	watts	Btu per hour	3.413
Btu per sq ft-hr	kilocalories per sq meter-hr	2.711	kilocalories per sq meter-hr	Btu per sq ft-hr	0.3688
Btu per cu ft-hr	kilocalories per cu meter-hr	8.897	kilocalories per cu meter-hr	Btu per cu ft-hr	0.112
pounds per 1000 pounds(gas)	grams per cu meter	1.205	grams per cu meter (gas)	pounds per 1000 pounds	0.93
grains per cu ft (68 F)	grams per cu meter (20 C)	2.28	grams per cu meter (20 C)	grains per cu ft (68 F)	0.43

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TABLE EXCHANGE RATES FOR SIX EUROPEAN COUNTRIES,
(NATIONAL MONETARY UNIT PER U.S. DOLLAR)
1948 TO FEBRUARY, 1978(a)

	Denmark Kroner (D.Kr.)	France Francs (F.Fr.)	W. Germany Deutsch Mark (D.M.)	Netherlands Guilders (Gl.)	Sweden Kronor (S.Kr.)	Switzerland Francs (S.Fr.)
1948	4.810	2.662	3.333	2.653	3.600	4.315
1949	6.920	3.490	4.200	3.800	5.180	4.300
1950	6.920	3.499	4.200	3.800	5.180	4.289
1951	6.920	3.500	4.200	3.800	5.180	4.369
1952	6.920	3.500	4.200	3.800	5.180	4.285
1953	6.920	3.500	4.200	3.786	5.180	4.288
1954	6.914	3.500	4.200	3.794	5.180	4.285
1955	6.914	3.500	4.215	3.829	5.180	4.285
1956	6.914	3.500	4.199	3.830	5.180	4.285
1957	6.914	4.199	4.202	3.791	5.173	4.285
1958	6.906	4.906	4.178	3.775	5.173	4.308
1959	6.908	4.909	4.170	3.770	5.181	4.323
1960	6.906	4.903	4.171	3.770	5.180	4.305
1961	6.886	4.900	3.996	3.600	5.185	4.316
1962	6.902	4.900	3.998	3.600	5.186	4.319
1963	6.911	4.902	3.975	3.600	5.200	4.315
1964	6.921	4.900	3.977	3.592	5.148	4.315
1965	6.891	4.902	4.006	3.611	5.180	4.318
1966	6.916	4.952	3.977	3.614	4.180	4.327
1967	7.462	4.908	3.999	3.596	5.165	4.325
1968	7.501	4.948	4.000	3.606	5.180	4.302
1969	7.492	5.558	3.690	3.624	5.170	4.318
1970	7.489	5.520	3.648	3.597	5.170	4.316
1971	7.062	5.224	3.268	3.254	4.858	3.915
1972	6.843	5.125	3.202	3.226	4.743	3.774
1973	6.290	4.708	2.703	2.824	4.588	3.244
1974	5.650	4.444	2.410	2.507	4.081	2.540
1975	6.178	4.486	2.622	2.689	4.386	2.620
1976	5.788	4.970	2.363	2.457	4.127	2.451
1977	5.778	4.705	2.105	2.280	4.670	2.010
1978 (Feb.)	5.580	4.766	2.036	2.176	4.615	1.987

(a) Exchange Rate at end of period.

Line "ae" Market Rate/Par or Central Rate.

Source: International Financial Statistics 1972 Supplement; April, 1978, Volume XXXI, No. 4, Published by the International Monetary Fund.

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